ENVIROSAT—2000 Report

Comparison of the Defense Meteorological Satellite Program (DMSP) and the NOAA Polar-orbiting Operational Environmental Satellite (POES) Program

October 1985

ENVIROSAT-2000

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service

ENVIROSAT–2000 Report

Comparison of the Defense Meteorological Satellite Program (DMSP) and the NOAA Polar-orbiting Operational Environmental Satellite (POES) Program

E. Larry Heacock, Editor

NOAA Authors:

J. Bailey
L. Barbieri
A. Booth
W. Callicott
D. Cotter
R. Gird
G. Hunolt
C. Jones
T. Karras
R. Legeckis
D. MacCallum
E. Mack

P. McClain
D. Miller
J. Nichols
W. Pichel
W. Planet
R. Popham
A. Schwalb
L. Shaffer
D. Tarpley
B. Watkins
M. Weaks
D. Weiss

DOD Authors:

Col. A. Ramsay
Col. Q. Wilkes
Lt. Col. R. Picanso
Cmdr. W. Shutt
Maj. W. Agrella
Maj. R. Borchers
Lt. Cmdr. L. Burgess
Maj. B. Higbie, Jr.
Maj. G. Logan
Capt. M. Focht

Washington, D.C.
October 1985

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
Anthony J. Calio, Administrator

National Environmental Satellite, Data, and Information Service
William P. Bishop, Acting Assistant Administrator

COMPARISON OF THE DEFENSE METEOROLOGICAL SATELLITE PROGRAM (DMSP) AND THE NOAA POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE (POES) PROGRAM

ABSTRACT

This report offers a technical comparison of the two United States operational space programs that are based on the capabilities of polar-orbiting environmental satellites. The U.S. Air Force manages and conducts the operations of the Defense Meteorological Satellite Program (DMSP); the National Oceanic and Atmospheric Administration has the same responsibilities with respect to the NOAA Polar-orbiting Operational Environmental Satellite (POES) program. The report examines the major missions and goals of the two programs, the management and operational procedures that they follow, and the support they extend to each other and to other Federal agencies. Detailed discussions are provided about the specifications and performance characteristics of the spacecraft, sensors, onboard systems, command and control systems, and communications systems employed by the two programs. An extensive relative analysis of the operation and uses of the DMSP and POES imaging and atmospheric sounding instruments is provided. Other sensors and systems are discussed, as is the joint agreement between DOD and NOAA for sharing their satellite data and data processing load. Nonmeteorological users of DMSP and POES data are described. The organization and content of the satellite data archive are presented. Near-future system improvements and longer-term mission requirements are also discussed.

TABLE OF CONTENTS

Chapter Page

Abstract i

I. INTRODUCTION I-1

II. COMPARISON OF DMSP AND POES PROGRAMS II-1

A. Major Missions II-1
  1. Defense Meteorological Satellite Program (DMSP) II-1
  2. Polar-orbiting Operational Environmental Satellite (POES) II-7
B. Programmatics II-14
  1. DMSP II-14
  2. POES II-23
C. Operational Procedures II-25
  1. DMSP II-25
  2. POES II-36
D. Fit With Other Agency Programs II-39
  1. DMSP II-39
  2. POES II-44

III. TECHNICAL COMPARISON III-1

A. Bus Comparison III-1
  1. DMSP III-1
  2. POES III-24
  3. Bus Comparison III-50
B. Sensor Complements III-56
C. Engineering Characteristics of Sensors III-60
  1. DMSP III-60
  2. POES III-60
D. Onboard Automation of Processing and Operation III-68
  1. DMSP III-68
  2. POES III-70
E. Command and Control Overview III-105
  1. DMSP III-105
  2. POES III-110
F. Communications III-116

IV. RELATIVE ANALYSES AND USES OF DMSP AND POES IMAGERS IV-1

A. Operational Linescan System (OLS) IV-1
  1. Instrument Description IV-1

TABLE OF CONTENTS (continued)

Chapter Page

2. Spectral and Spatial Resolution IV-3
3. Radiometric Calibration IV-10
4. Radiometric and Geometric Precision IV-10
5. Imaging/Radiometric Applications IV-12
6. Data Availability IV-22

B. Sensor System Microwave Imager (SSM/I) IV-23
1. Spectral and Spatial Resolution IV-23
2. Radiometric Calibration IV-24
3. Radiometric and Geometric Precision IV-24
4. Imaging/Radiometric Applications IV-30
5. Data Availability IV-32

C. Advanced Very High Resolution Radiometer (AVHRR/2) IV-32
1. Instrument Description IV-32
2. Operating Characteristics IV-34
3. Radiometric Calibration IV-35
4. Radiometric and Geometric Precision IV-38
5. Imaging/Radiometric Applications IV-40
6. Data Availability IV-42

V. RELATIVE ANALYSES AND USES OF DMSP AND POES SOUNDERS V-1

A. DMSP Sounding Instruments V-1
1. Microwave Temperature Sounder (SSM/T) V-1
2. Microwave Water Vapor Sounder (SSM/T-2) V-6
3. Infrared Temperature and Water Vapor Sounder (SSH-2) V-9

B. TIROS Operational Vertical Sounder (TOVS) V-11
1. Instrument Descriptions - Characteristics .. V-11
2. Radiometric Calibration V-21
3. Sounding Precision V-26
4. Sounding Applications V-27
5. Data Availability V-29
6. Channel Selection V-31

VI. RELATIVE ANALYSES AND USES OF OTHER SENSORS VI-1

A. Precipitating Charged Particle Spectrometer (SSJ/4) VI-1
B. Topside Ionospheric Plasma Monitor (SSI/E) VI-3
C. Ionospheric Plasma Drift/Scintillation Monitor (SSI/ES) VI-5
D. Fluxgate Magnetometer (SSM) VI-7
E. Vacuum Ultraviolet Spectrometer (SSUV) VI-7

TABLE OF CONTENTS (continued)

Chapter Page

1. Daytime Low- to Mid-latitudes VI-9
2. Nighttime Mid-latitudes VI-9
3. Auroral E-Layer VI-9
4. Equatorial Daytime VI-11

F. Space Radiation Dosimeter (SSJ*) VI-11
G. Gamma and X-Ray Spectrometer (SSB/A) VI-14
H. Gamma and X-Ray Detector (SSB/S and SSB/X) VI-14
I. Space Environment Monitor (SEM) VI-17
1. Total Energy Detector (TED) VI-17
2. Medium-Energy Proton and Electron Detector (MEPED) VI-19
3. Data Processing Unit (DPU) VI-24
4. Application and Data Examples VI-24

J. Solar Backscatter Ultraviolet Instrument (SBUV/2) VI-29
1. Scientific Rationale VI-29
2. Instrument System VI-30
3. Theoretical Foundations VI-31
4. Operational Phases VI-31
5. Applications VI-32

K. Argos Data Collection and Location System (DCLS) VI-33
1. Monitoring VI-34
2. Argos Subsystems VI-34
3. Argos System Applications VI-42

L. Search and Rescue Satellite-Aided Tracking (SARSAT) VI-50
1. System Concept VI-50
2. Operating Characteristics VI-52
3. Space Segment VI-53

VII. ANALYSES OF ORBITAL REQUIREMENTS VII-1

A. Timeliness and Geographic Coverage VII-1
1. DMSP VII-1
2. POES VII-2

B. Input to Analysis/Forecast Models VII-2
1. DMSP VII-2
2. POES VII-3

VIII. INTERNATIONAL ASPECTS OF POES VIII-1

A. Lannion CDA Support for NOAA Polar Satellites .. VIII-1
1. Lannion Data Flow VIII-1
2. Future VIII-1

TABLE OF CONTENTS (continued)

Chapter Page

B. Stratospheric Sounding Unit/Advanced Microwave Sounding Unit VIII-3
C. Argos Data Collection and Platform Location System VIII-3
D. COSPAS/SARSAT VIII-7
  1. Present System VIII-7
  2. Future Systems VIII-9
E. DMSP VIII-9

IX. DOMESTIC AND INTERNATIONAL BROADCAST SERVICES IX-1

A. APT, HRPT, and DSB Services of POES IX-1
  1. Domestic Role IX-1
  2. International Role IX-4
  3. Conclusions IX-5
B. SARSAT H, I, J and Beyond IX-5
C. DMSP Direct Broadcasts to Tactical Terminals .. IX-6

X. SHARED PROCESSING X-1

A. System Description X-1
B. Centers of Expertise X-3
C. Product Mix X-4
D. Implementation Schedule X-6

XI. ROLE OF OLS AND AVHRR IN NONMETEOROLOGICAL APPLICATIONS XI-1

A. OLS XI-1
  1. Oceanography XI-1
  2. Hydrology XI-3
  3. Volcanic Eruption Monitoring XI-4
  4. Auroral Oval Mapping XI-7
  5. Miscellaneous XI-7
B. AVHRR XI-11
  1. Agricultural Uses of AVHRR Data XI-11
  2. Hydrology XI-16
  3. Other Land Applications XI-19
  4. Oceanographic and Sea Surface Temperature XI-20

XII. FUTURE MISSION REQUIREMENTS XII-1

A. Future DMSP Requirements XII-1

TABLE OF CONTENTS (continued)

Chapter Page

B. Future POES Requirements XII-1
  1. Current NOAA Series Spacecraft (NOAA E Through J) XII-2
  2. NOAA K, L, M XII-2
  3. Future DMSP and POES Microwave Sounder Complementarity XII-9
  4. Future NOAA Series Satellite Systems XII-9

XIII. NOAA ARCHIVING AND RETROSPECTIVE USERS XIII-1

A. Overview of the NOAA Satellite Archive Center XIII-1
B. NOAA POES Data--NOAA Archive Data Base and Users XIII-2
  1. Contents of the POES Archive Data Base XIII-2
  2. Near-Real-Time and Retrospective Users XIII-2
  3. Planned Changes in NOAA's POES Archive Data Base and User Services XIII-6
C. DMSP Data--NOAA Archive Data Base and Users XIII-7
  1. Contents of the DMSP Archive Data Base XIII-7
  2. Retrospective Users XIII-8
  3. Planned Changes in NOAA's DMSP Archive Data Base and User Services XIII-8

XIV. CONCLUSIONS XIV-1

A. Overview XIV-1
B. Outlook XIV-2

Appendix

A. Glossary of Acronyms A-1

Index to Tables

Table Page

II-1 DMSP Acquisition Strategy Comparative Summary II-15
II-2 Savings and Cost Avoidance II-16
II-3 DMSP Command and Control Communications Frequencies II-28
II-4 DMSP Tactical Terminal Locations II-32

III-1 DMSP/POES System Descriptions and Differences III-3
III-2 DMSP/POES Weight Summary III-9
III-3 Satellite/Ground System Interface Summary III-26
III-4 Spacecraft Motion Versus Thrusters III-39
III-5 Software Sizing by Subsystem III-46
III-6 Bus Heritage and Growth III-53
III-7 POES/DMSP Sensor Comparison III-57
III-8 Engineering Characteristics of DMSP Sensors III-61
III-9 Mission Sensor Temperature Requirements III-62
III-10 Data Handling Subsystem Major Component List III-71
III-11 Data Handling Subsystem Data Inputs III-74
III-12 Data Handling Subsystem Data Outputs III-75
III-13 Data Handling Subsystem Clocks and Sync Signals III-76
III-14 TIP Boost Mode Format Parameters III-77
III-15 TIP Orbit Mode, CPU Dump Mode, and Single-Point Dwell Mode Format Parameters III-77
III-16 MIRP High-Resolution Transmission and Local Area Coverage Format Parameters III-78
III-17 MIRP Global Area Coverage Format Parameters III-79
III-18 APT Format Parameters III-79
III-19 Digital Tape Recorder Performance Summary III-81
III-20 MIRP Data Sample Times III-92
III-21 APT Earth Data Processing Regions III-102
III-22 APT Grey-Scale Parameters III-102
III-23 POES Communications Frequencies III-118

IV-1 Imager Technical Comparison IV-2
IV-2 OLS Data Specifications IV-4
IV-3 DMSP Data Processing/Application (Current) IV-17
IV-4A Military Missions Versus Environmental Parameters--Air Force IV-18
IV-4B Military Missions Versus Environmental Parameters--Army IV-20

Index to Tables

Table Page

IV-4C Military Missions Versus Environmental Parameters--Navy IV-21
IV-5 SSM/I Data Specifications IV-27
IV-6 SSM/I Functional System Requirements IV-28
IV-7 SSM/I Geometric Resolution IV-29
IV-8 DMSP Data Processing/Application (Future) IV-31

V-1 Sounder Technical Comparison V-2
V-2 SSM/T Channel Parameter Requirements V-3
V-3 SSM/T Key Scan Parameters V-4
V-4 SSM/T Data Specifications V-5
V-5 SSM/T-2 Data Specifications V-7
V-6 SSH-2 Data Specifications V-10
V-7 HIRS/2 System Parameters V-12
V-8 HIRS/2I Spectral Requirements V-15
V-9 SSU Characteristics V-17
V-10 MSU Instrument Parameters V-19
V-11 Data Products From TOVS V-27

VI-1 Solar/Ionospheric Data Sources VI-2
VI-2 SSJ/4 Data Specifications VI-4
VI-3 SSI/E, SSI/ES Data Specifications VI-6
VI-4 SSM Data Specifications VI-8
VI-5 SSUV Data Specifications VI-10
VI-6 SSJ* Data Specifications VI-13
VI-7 SSB/A Data Specifications VI-15
VI-8 SSB/S and SSB/X Data Specifications VI-16
VI-9 SBUV/2 Ozone Products VI-33
VI-10 Argos Platform Characteristics VI-37
VI-11 Argos Pass Frequency and Duration VI-38

X-1 Environmental Parameters for Selected Surface Types X-5

XII-I Advanced TIROS-N (NOAA E Through J) Summary Sheet XII-3
XII-2 Polar Imagers and Sounders (NOAA E Through J) XII-4
XII-3 Polar Imagers and Sounders (NOAA K, L, M) XII-5
XII-4 Projected Payload Complement for NOAA D Through M Satellites XII-10

Index to Tables

Table	Page
XII-5 NOAA K, L, M Changes	XII-11
XII-6 Future Microwave Sounder Technical Comparison	XII-12
XIII-1 Summary Listing of POES Satellite Data Archived by SDSD	XIII-3
XIII-2 Operational POES Products Archived by SDSD	XIII-4
XIII-3 POES Data and Products Provided by SDSD in FY84	XIII-5
XIII-4 POES Data Users by User Class, FY84	XIII-6

Index to Figures

Figure Page

II-1 DMSP System Overview II-3
II-2 Planning, Programming, and Budgeting System II-20
II-3 Mark IV Tactical Van II-29
II-4 Air Force DMSP Tactical Facilities and Data Flow II-31
II-5 AFGWC DMSP Data and Products Flow II-35

III-1 POES/DMSP System Overview III-2
III-2 Orbital Configuration of a Block 5D-2 Satellite III-11
III-3 Satellite Orbital Configuration III-12
III-4 Launch and Ascent Sequence III-13
III-5 Ascent Trajectory III-14
III-6 Satellite Structure Subsystem III-17
III-7 POES Mission-Orbit Configuration III-25
III-8 Satellite Internal Arrangement III-28
III-9 POES Satellite Characteristics III-30
III-10 Overall POES Functional Block Diagram III-33
III-11 ADACS Simplified Block Diagram III-35
III-12 RCE Functional Schematic III-38
III-13 Communication and Data Handling Subsystem Block Diagram III-41
III-14 Command and Control Subsystem Block Diagram III-44
III-15 Electrical Power Subsystem Block Diagram III-48
III-16 Subsystem Commonality (DMSP/POES) III-52
III-17 Data Handling Subsystem Functional Block Diagram III-72
III-18 TIP Boost Mode Format III-83
III-19 TIP Orbital Mode Format III-84
III-20 HRPT/LAC Frame Format III-89
III-21 Sixth and Tenth Degree Polynomial Generators III-90
III-22 Method of Randomization for LAC/GAC Data III-94
III-23 GAC Frame Format III-95
III-24 APT Frame Format III-97
III-25 APT Video Line Format (Prior to D/A Conversion) III-98
III-26 APT Sync Details III-101
III-27 APT 16-Point Telemetry Frame III-104
III-28 DMSP Satellite Operations Group Overview III-109
III-29 Functional POES Payload Command and Control System III-111

Index to Figures

Figure Page

IV-1 DMSP Visible, Infrared, and Low Light Visible Imagery (Italy) IV-5
IV-2 Near-Terminator Problem IV-8
IV-3 Dynamic Range Requirements for DMSP OLS Terminator Coverage IV-9
IV-4 T Calibration and Clamp IV-11
IV-5 AFGWC Automated Cloud Analysis IV-15
IV-6 DMSP Tactical Imagery IV-25
IV-7 AVHRR Signal Path From Detectors to MIRP IV-36

V-1 Northern Hemisphere 24-Hour POES Sounding Density (two-satellite coverage) V-30

VI-1 TED Spiraltron Detector and Electrostatic Analyzer Assembly VI-18
VI-2 Ramp Characteristics VI-20
VI-3 TED Functional Block Diagram VI-21
VI-4 Omnidirectional Spectrometer VI-23
VI-5 TIROS-N DPU Block Diagram VI-25
VI-6 Area of Satellite Coverage VI-36
VI-7 Argos Telemetry Ground Stations VI-39
VI-8 File Creation VI-41
VI-9 Sketch of Casid Buoy VI-43

VIII-1 NOAA Polar-Orbiting Satellite Wide-Band Data Communications Links VIII-2
VIII-2 Lannion Segment of Western European System (WES) VIII-4
VIII-3 Lannion/Wallops/SOCC Polar System VIII-5

X-1 Shared Processing Network Configuration X-2
X-2 Shared Processing Master Schedule X-7

XI-1 DMSP Polar Ice Imagery XI-5
XI-2 DMSP Nighttime Visible Imagery of the Aurora XI-9
XI-3 DMSP Imagery of Forest Fire Smoke off the East Coast of Central Florida XI-13
XI-4 Composite Monthly Mean Sea Surface Temperature Analysis XI-22
XI-5 Objective Analysis of Sea Surface Temperature From Satellite Data XI-23
XI-6 High-Resolution Sea Surface Thermal Analysis XI-24

Index to Figures

Figure | Page

XI-7 Sea Surface Temperature Field Analyzed From GAC (4 km Resolution) Data XI-25
XI-8 Oceanographic Analysis Product XI-27

XII-1 Weighting Function, AMSU-A, NOAA K, L, M XII-7

I. INTRODUCTION

This report is a compilation of technical information about the two United States operational polar-orbiting environmental satellite programs. These programs are:

- The Defense Meteorological Satellite Program (DMSP), managed and conducted for the Department of Defense by the U.S. Air Force

- The civil Polar-orbiting Operational Environmental Satellite (POES) program, managed and conducted by the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce

The purpose of this report is to provide a source of technical information about the two programs in a format that aids comparisons between them. Several sections of the report were contributed by authors who are also the operators of the two systems. This approach results in some overlap among sections and topics. Overlap and divergent discussions of similar subjects have been retained where they might aid the reader's understanding of the day-to-day workings of the two programs.

This document presents a view of the two systems limited in scope to the present and the near future. The near future is defined as covering those program elements currently extant and those elements for which budget authority has already been obtained in principle. (Note that this allows description of some elements for which future appropriations may be required to complete work.)

One of the purposes of this document is to establish the technical threshold (phase A) from which FY86 and FY87 funded studies (phase B) can be initiated. The contractors undertaking these studies will be required to examine the two programs in fine technical detail and report on opportunities for further technical collaboration, joint projects, and cross-support between the programs. Because this document was prepared with this purpose in view, it is the most thorough and complete technical study of the DMSP and POES systems that has ever been published.

II. COMPARISON OF DMSP AND POES PROGRAMS

A. MAJOR MISSIONS

1. Defense Meteorological Satellite Program (DMSP)

a. NSDD42. The following is an extract from National Security Decision Directive (NSDD) #42, July 4, 1982 (emphasis added):

> National Security Space Program. The United States will conduct those activities in space that it deems necessary to its national security. National security space programs shall support such functions as command and control, communications, navigation, environmental monitoring, warning, surveillance and space defense. The following states the policies which shall govern the conduct of the national security program.
>
> Survivability. Survivability and endurance of space systems, including all system elements, will be pursued commensurate with the planned use in crisis and conflict, with the threat, and with the availability of other assets to perform the mission. Deficiencies will be identified and eliminated, and an aggressive, long-term program will be undertaken to provide more assured survivability and endurance.
>
> Security. Security, including dissemination of data, shall be conducted in accordance with Executive Orders and applicable directives for protection of national security information, and commensurate with both the missions performed and the security measures necessary to protect related space activities.

b. Joint Service Memorandum of Agreement. The following extract is taken from the Memorandum of Agreement (MOA) on the Joint Service Management and Operation of the Defense Meteorological Satellite Program (DMSP), Nov. 11, 1976:

> Purpose. This MOA establishes the management policy and areas of responsibility for the Departments of the Army, Navy, and Air Force relative to the acquisition, operation, and support of the Defense Meteorological Satellite Program (DMSP), and the Department of Defense (DOD) meteorological satellite system.
>
> Operations. Time separation of satellites will be optimized for both strategic and tactical missions according to established priorities. The Commander, Air Force Global Weather Central (AFGWC), is responsible to assure both strategic mission coverage, and equitable allocation of direct data coverage among the Services. An Operational Requirements

Group, composed of representatives of the Services, shall be formally constituted at the AFGWC and shall be responsible for reviewing the operational performance of the satellites, and periodically advising the Executive Manager and the Services of their findings. This group will also collect and prioritize, in accordance with agreed upon guidelines, the direct data requirements and recommend allocation of direct data coverage to the Commander, AFGWC.

c. Generic Mission Statement and Requirements

Mission. The mission of the DMSP is to provide, through all levels of conflict, consistent with the survivability of the supported forces, global visible and infrared cloud data and other specialized meteorological, oceanographic, and solar-geophysical data required to support worldwide DOD operations and high-priority programs. The DMSP's primary mission is to support highly classified programs with presidential interest that are assigned the highest U.S. Air Force (USAF) precedence. Timely data are supplied to the AFGWC, the Navy Fleet Numerical Oceanography Center (FNOC), and tactical receiving terminals deployed worldwide.

System Definition. The system of DOD meteorological satellites, communication links, and ground facilities that acquire and transmit the environmental data and perform the initial processing, as needed to satisfy the DOD requirements, is known as the Defense Meteorological Satellite System (DMSS). The requirements for environmental monitoring, as levied by the DOD, apply to the DMSS as a whole. As space-based environmental sensing systems requirements are validated and funded, their implementation may be assigned, as appropriate, either to the Joint Service DMSP, to another program under the DMSS, or to an independent program.

System Description. The DMSP is a total satellite system composed of spacecraft with sensors, an Earth-based command and control network, user stations, launch vehicle and support, and a communication network linking the various segments together. The space segment consists of satellites at 450 nmi sun-synchronous polar orbits. Real-time weather data are transmitted directly from the spacecraft to Air Force and Navy ground terminals, and Navy carriers located throughout the world. Stored or playback meteorological data are transmitted to the AFGWC at Offutt AFB, Nebraska, and to the FNOC in Monterey, California, for processing and distribution (fig. II-1).

System Performance Requirements. Requirements imposed on the DMSS have their origin in the generation of Statements of Operational Need (SONs) by the USAF Military Air Command (MAC) and of Operational Requirements (ORs) by the Office of the

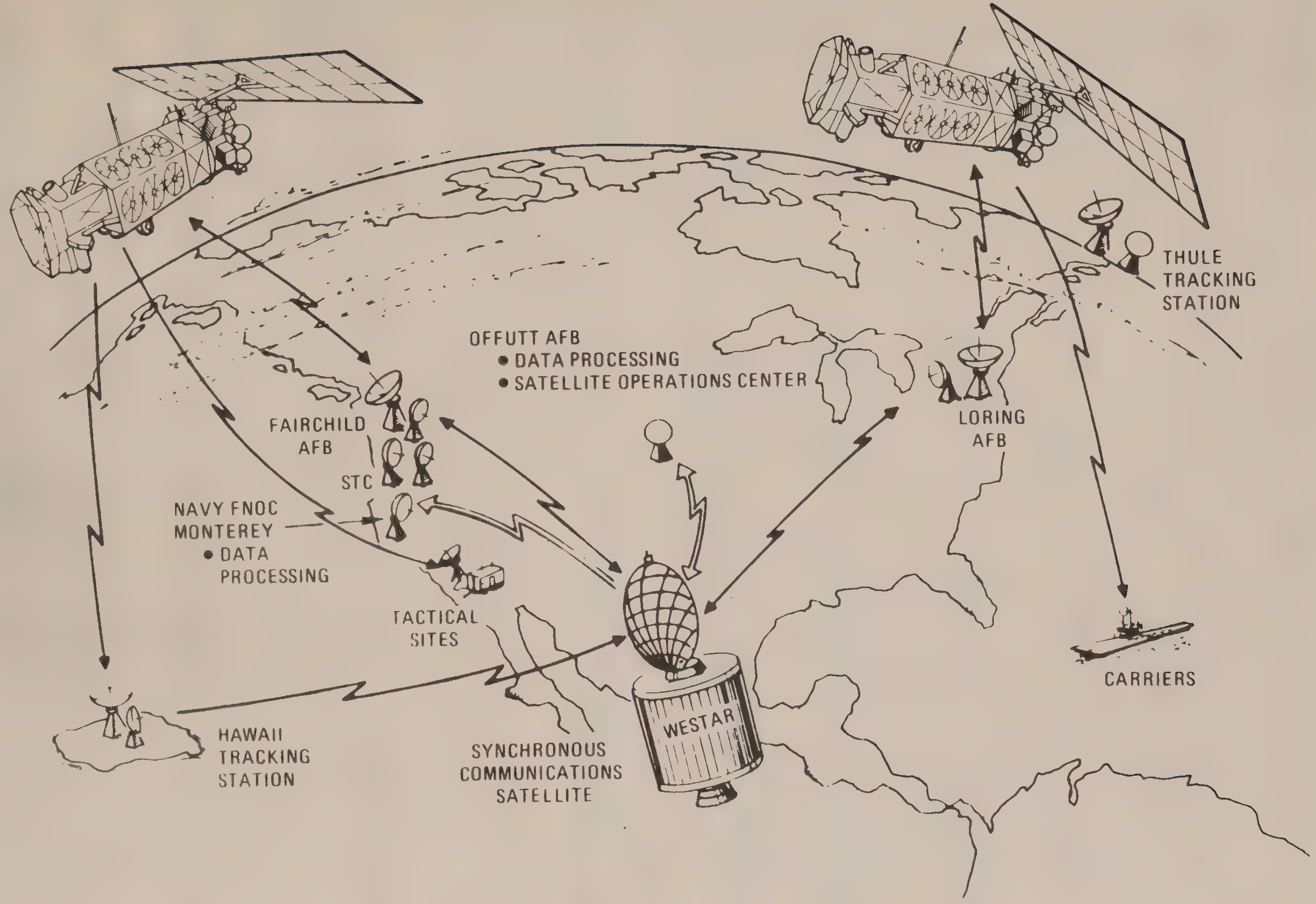

THULE TRACKING STATION
OFFUTT AFB
● DATA PROCESSING
● SATELLITE OPERATIONS CENTER
FAIRCHILD AFB
STC
LORING AFB
NAVY FNOC MONTEREY
● DATA PROCESSING
TACTICAL SITES
CARRIERS
WESTAR
HAWAII TRACKING STATION
SYNCHRONOUS COMMUNICATIONS SATELLITE

Figure II-1
DMSP System Overview

Chief of Naval Operations (CNO). A subset of these requirements is applicable to the DMSP. SONs are generated by MAC on the basis of operational requirements for environmental services levied by the U.S. Air Force and Army commands, and are submitted for validation to the Air Staff and the Joint Chiefs of Staff (JCS). They include Precipitation and Soil Moisture Mapping (PREMAP - MAC 507-78), Pre-Strike Surveillance/Reconnaissance System (PRESSURS - MAC 508-78), Remote Atmospheric Soundings (REAMOS - MAC 505-79), Ionospheric Sensing (IONS - MAC 02-80), and Space Environmental Monitoring (SEM - MAC 01-83). Similarly, the OR for Satellite Measurement of Oceanographic Parameters (SMOP), and the ORs for Geophysical Data Measurements From Satellites (OR 78) and for Navy Operational and Research Requirements for Environmental Data Measurements From Satellites (OR 80), delineate requirements for operational and research environmental services in support of U.S. Navy and Marine Corps commands. These requirements are validated and prioritized at the JCS level. The currently validated requirements contained in MJCS 251-76 and MJCS 289-77, and the military requirements and prioritizations contained in MJCS 195-81, will be amended periodically by JCS memoranda as requirements dictate. Such requirements impact the design, configuration, and operation of one or more system segments, identified for DMSP as the Space Segment (SS), Command Control and Communications Segments (C^3S), and User Segment (US).

DMSS Data Requirements Documents. (The following is an excerpt from DMSP Systems Requirement Document, Dec. 14, 1983.)

MJCS 251-76 31 Aug 76	Revalidation of Military Requirements for Meteorological Satellite Data (Memorandum from the JCS to the Director, Defense Research and Engineering).
MJCS 289-77(S) 30 Sept 77	Operational Requirements for Satellite Monitoring of the Earth's Space Environment (U) (Memorandum from the JCS for the Director, Defense Research and Engineering).
MJCS 195-81(S) 5 Oct 81	Requirements for DMSP (U) (Memorandum from the JCS for the Chief of Staff, USAF).
MAC/XPPE 19 Oct 78	DMSP/TIROS Convergence Study (Memorandum from MAC/XPPE to USAF/RDSL).
MAC 507-78 28 Dec 78	Statement of Operational Need (SON) for Precipitation and Soil Moisture Mapping (PREMAP). Validated 5 Jun 79.

MAC 508-78 28 Dec 78	Statement of Operational Need (SON) for Pre-Strike Surveillance/Reconnaissance System (PRESSURS). Validated Dec 79.
MAC 505-79 30 Sep 79	Statement of Operational Need (SON) for Remote Atmospheric Soundings (REAMOS). Validated 3 Jun 81.
MAC 02-80 21 Mar 80	Statement of Operational Need (SON) for Ionospheric Sensing (IONS). Validated 3 Jun 81.
MAC 01-83 12 Apr 85	Statement of Operational Need (SON) for Space Environmental Monitoring (SEM). (In validation process at HQ USAF).
OP-945/ Ser 61297 26 Oct 76	Navy Requirements for DMSP Spacecraft in the 1980's (Memorandum from CNO to Commanding Officer, Navy Space Systems Activity).
Ser 987/139703 10 Feb 77	Operational Requirement (OR) Satellite Measurement of Oceanographic Parameters (SMOP) (OR-W0527-OS).
Ser 952C412/ 631349 15 Sep 78	Operational Requirements for Geophysical Data Measurements from Satellites (Memorandum from CNO to CO, Naval Space Systems Activity).
NRL 4006-15 26 Feb 80	Minutes of Naval Environmental Remote Sensing Coordinating and Advisory Committee (NERSAC) meeting of 1 Feb 1980.

(NOTE: These documents are summarized in the DMSS Systems Requirements Document, Dec. 14, 1983, Appendix A.)

Military Requirements. The following discussion of requirements is based upon MJCS 195-81, Oct. 5, 1981:

- Primary Data Requirement
  (Visible and IR Imagery, Atmospheric/Oceanographic)

  -- Fundamental Requirements

    --- Timeliness: Ground capabilities to process stored and direct readout data within minutes of receipt. Delivery to AFGWC is required within 15 minutes of observation, 24 hours per day.

    --- Data Type/Resolution: Day and night, constant

--- Cross-Track Resolution Data as Follows (listed in order of importance):

----1.5 nmi IR, 1.5 nmi visible, 0.3 nmi IR, 0.3 nmi visible. (Centralized applications)

----0.3 nmi visible, 0.3 nmi IR, 1.5 nmi visible, 1.5 nmi IR. (Tactical applications)

--- Data Location Accuracy: Within approximately 1 nmi at edge of scan.

-- System Requirements

--- Availability: n satellites continuously on orbit; secure, responsive DOD command and control.

--- Coverage: Global at least 2n times per day.

--- Orbit: n orbits, normally sun-synchronous, with flexible nodal time selection capability prior to launch of each satellite.

--- Survivability: Satellites and communications must be protected so that military data support will continue uninterrupted during conflict.

--- Data Security: Data must have the capability for encryption so that transmission can be effected without compromise of data during periods of conflict.

- Other Data Requirements
(Only current major requirements, ref. DMSS System Requirement Document, Dec. 14, 1983.)

-- Meteorological

--- Wind Soundings

--- Temperature Soundings

--- Water Vapor Soundings, Precipitation, Liquid Water Content, Soil Moisture

-- Oceanographic

--- Sea Surface Temperature

--- Sea State

--- Sea Surface Winds

        - Sea Surface Topography

    - Ionospheric

        - Precipitating Electrons
        - Ionospheric Plasma and Scintillation
        - Electron Density Soundings

- Other Payloads
  Other nonenvironmental payloads are carried aboard DMSP spacecraft based upon current requirements/capabilities.

- Other Requirements

    - Increase number of satellites configured with the primary sensor and with mission sensors as practical, to enhance frequency of global coverage.

    - Improve existing sensors or add sensors to satisfy portions of validated requirements not currently being met, to include technology development necessary for such improved sensors.

Capabilities Comparison. It should be noted that the primary DOD requirement is for imagery, and the primary civil requirement is for vertical temperature and moisture profiles. POES imagery does not meet DOD requirements for timeliness, resolution (either at nadir or across the sensor swath), nighttime visible capability, or operational flexibility.

2. Polar-orbiting Operational Environmental Satellite (POES)

There has been a clear and consistent definition of civil and defense roles in the application of space technology, beginning with the National Space Act of 1958 and continuing through the issuance of the most recent restatements of national space policy. The DOD is to apply this technology to the military and security needs of the Nation, while the civil program is to promote U.S. scientific and technological leadership, satisfy domestic needs, and promote an open, cooperative, and positive international image.

As applied to the management functional structure of the Nation's operational environmental satellite systems, this policy has been even more carefully established and its details more precisely articulated. The intense 1973 review of the status of these environmental satellite systems, as well as the extensive 1977-78 and 1981-82 reexamination of these issues, each reaffirmed and further specified the standing national policy relating to these systems.

The most recent statement of national space policy released July 14, 1982 (NSDD-42), continued the separation of civil and national security space programs. NSDD-42 further defined the role of the National Oceanic and Atmospheric Administration (NOAA)/Department of Commerce as the manager of Federal civil operational space remote-sensing systems.

As a result of system planning and implementation activities carried out by the DOD and NOAA in accordance with policy direction:

- Separate systems under separate management, but sharing common components, have been developed and continued (emphasis added).
- The international commitment of the civil system has been expanded.
- The capabilities of the military system have been developed to meet more completely the full range of DOD needs.

The civil system's primary mission is to provide regular and reliable global coverage (quantitative soundings and radiance measurements) from satellites in circular sun-synchronous orbits. This primary mission will be revised only if the data requirements specified by the National Weather Service (NWS) are changed. The requirements for quantitative data from satellites will be increased in the 1990's.

Reliable and continuous service from the operational satellites remains a dominant design criterion. Redundancy must be provided in the form of redundant primary spacecraft systems and sensors aboard each satellite, or sufficient satellites must be orbited to meet the primary program mission requirements. If adequate sensor system redundancy cannot be provided on each satellite, the redundancy requirement must be met by having two operational satellites in orbit at all times, thus continuing the present two-satellite system. This two-satellite configuration, in addition to ensuring that some global data continue to be available in the event of a launch failure or premature failure in orbit, provides the additional advantage of supplying data sets that further strengthen long-term weather forecasts.

A nominal schedule of a launch every 12 months, with the provision for 120-day call-up for launch upon a satellite failure, is required to ensure continuity of data.

Design lifetime of the NOAA satellites will be increased if technically feasible and cost effective. The baseline for today's spacecraft is 2 years of on-orbit life.

The satellites provide continuous direct data broadcasts to ground stations. Changes in existing direct broadcast services will be made only after consideration of the impacts of such changes on the existing international community of ground receiving stations.

Routine relay of sensor data from in situ platforms, and determination of geographic location of those platforms, such as oceanic buoys, ships, automatic stations, aircraft, and balloons, are important in satellite services.

Collection and relay of messages from emergency transmitters borne by aircraft and ships as a part of the international Search and Rescue (SAR) program are now part of the NOAA operational program.

Spacecraft capacities (weight launched into orbit, space on the bus, data transmission capabilities, and power available) not required for primary mission purposes or committed to other programs will continue to be available for research purposes or for testing and evaluating new sensor systems.

The use of space-qualified sensors on the NOAA spacecraft has contributed to the reliability of the system. Previously, the National Aeronautics and Space Administration (NASA) has developed and flown prototypes of all the sensors and major spacecraft systems prior to their adoption for operational use. The loss of this NASA-funded parallel developmental program means that any new NOAA sensors will have to be space-proven on operational spacecraft. Either the operation will be parallel to the sensor being replaced, or NOAA must accept the risks of using the unproven sensor operationally.

a. Primary Versus Other Satellite Components. The test of whether a component is primary or less critical is: would a replacement satellite be launched (under a 120-day call-up scenario) if the component were to fail in orbit? Obviously there are many spacecraft components that are primary under this test: the power supply, navigation system, communications capabilities necessary to receive commands from the ground and transmit data to receiving stations, onboard computers, and certain tape recorders. Normal practice is to provide redundancy for these essential spacecraft components.

The satellite will be replaced if the sounder package or imaging radiometer were to fail, because the provision of soundings and radiance measurements is the primary mission of the POES. These sensors, and their associated tape recorders or data transmitters, are, therefore, primary components.

The following sensor systems and their tape recorders or data transmitters are important, but a satellite would not be replaced if they were to fail while the primary sensors were fully operational:

- In situ data collection and platform location services
- Search and Rescue service (may be moved to primary status in the 1990's)
- Space Environment Monitor
- Solar Backscatter Ultraviolet Radiometer
- Research and development components provided by NOAA, NASA, or other sources

b. International Data Exchange. Since the early 1960's, the United States has been the keystone of a highly cooperative and complex international data exchange network based on the fact that no nation can meet its needs for weather and ocean services without using data acquired by other countries. In this context, U.S. environmental satellites provide direct readout services to foreign as well as domestic users.

For the past two decades, the United States has encouraged the direct reception by countries worldwide of data from U.S. civil environmental satellites. One thousand stations in over 120 nations now receive directly at least some portion of their weather data from the NOAA satellites.

In addition to providing satellite data by direct readout, the United States makes satellite data and products available to all nations through the World Meteorological Organization's Global Telecommunication System (GTS).

No fees are charged for U.S. satellite data received either directly or through the GTS. Other national governments have joined the United States in the free exchange of satellite environmental data. Given its need for global weather data, the United States benefits equally from this pattern of free exchange of data. Indeed, foreign data are critical to many U.S. Government activities, both civil and military.

Consistent with this policy, the U.S. civil satellites (along with those of the U.S.S.R.) now carry Search and Rescue Satellite-Aided Tracking (SARSAT) transponders for relay of critical emergency signals from aircraft and ships in distress. The transponders are furnished by France as a contribution of the international Cosmicheskaya Sistyema Poiska Avariynich Sudov (COSPAS)/SARSAT program involving the United States, Canada, France, and the U.S.S.R.

c. Reliability and Data Continuity. A meteorological satellite system must provide a continuous and reliable source of data. The analysis and forecasting of the weather is an ongoing process that demands regular and routine knowledge (observations) of the current state of the atmosphere. This knowledge is required in four dimensions: two-dimensional spatial coverage in the horizontal to define weather patterns, a third dimension of the vertical structure of the weather patterns, and the fourth dimension of the time of the observation of the meteorological conditions. A loss of data for any period, either in space or time, is unacceptable, because gaps in the data input lead quickly to analysis errors, and to accelerating errors in forecasts. Both subjective and numerical forecasting techniques are only as good as the knowledge of the current and the immediate past (continuity) of the state of the atmosphere upon which the forecasts are based.

The loss of, or poor knowledge of, any data points in time or space for any extended period of time seriously handicap and degrade the forecasting process. Collection of weather data is like the gathering of current news or current military intelligence. The more often information is available, updated, and made current, the more value it has in decision making.

d. Coverage. The polar-orbiting system must provide global coverage. This means that an observation (datum) must be obtained at every point on the globe, with "point" being defined as the ground resolution of the primary sensors (30 km for the sounders and 1 km for the imaging radiometers). The present High Resolution Infrared Radiation Sounder (HIRS/2) provides a swath width of 2,240 km (distance perpendicular to the subpoint track of the satellite). Distance between orbits at the Equator is 2,822 km. At the present orbital altitude of about 870 km, the ground coverage of the sounder in successive orbits from a single satellite is not contiguous at the Equator; however, ground coverage does overlap poleward of the 34° latitudes. Data from the second satellite fill these equatorial gaps over a 24-hour period. For the present numerical forecast models, the equatorial data gaps are acceptable. The most critical data are the soundings poleward of the 34° N. to S. latitudes.

The present imaging Advanced Very High Resolution Radiometer (AVHRR), with its swath width of 2,900 km, does provide contiguous coverage at the Equator. This assures that sea surface temperature, Vegetation Index, and cloud cover data are available from a two-satellite operation four times daily over the entire globe.

The DMSP, operated by the Air Force, is flying a seven-channel microwave sounder designated the Sensor System Microwave/ Temperature (SSM/T). NOAA will process the data from this instrument for the DOD under the Shared Processing Agreement. The SSM/T is of similar design and of similar capability to the present Microwave Sounding Unit (MSU) operated by NOAA. The SSM/T will not meet NOAA's need for contiguous ground coverage, horizontal resolution, or vertical resolution. Under the Shared Processing Agreement, the DOD looks to NOAA for future improvements in sounding processing.

e. Time of Observations. To be useful for analyses and forecasts, sounding data must be gathered over large portions of the globe within fixed time constraints. Since the polar-orbiting satellites require time to traverse each orbit, and must rely on the rotation of the Earth beneath them to provide global viewing, the data are not gathered simultaneously or "synoptically," as is desired by current operational numerical analysis models. The numerical models will, however, accept data within ±3 hours of the primary synoptic times of 0000 Z and 1200 Z (Z refers to Greenwich mean time), and of the secondary synoptic times of 0600 Z and 1800 Z.

The present two-satellite POES system provides data valid (within ±3 hours) for use in numeric models initialized for both primary synoptic times. By international convention, radiosondes are released near 0000 Z and 1200 Z each day. The combination of satellite data and radiosonde data is the principal source of data for the primary synoptic analysis periods. Satellite data coverage of data-sparse (no radiosonde data) regions of the world (oceans, Southern Hemisphere, and polar regions) is critical to the proper analysis of the atmosphere, which in turn forms the basis of the 24-hour to 5-day numerical forecasts of global and regional weather.

The satellites are the principal source of sounding data that are valid for the "off-time" analysis cycles of 0600 Z and 1800 Z. Only surface data from conventional sources are normally available at these times. The numerical forecast models use the sounding data from satellites to maintain the continuity of analyzed fields, and to update continually the primary analyses of 1200 Z and 0000 Z. This process assures that the primary analyses are based on data that show consistency and continuity over 6-hour analysis update cycles, rather than the twice-daily updates possible if only conventional, international radiosonde network data are used.

f. Timeliness of Delivery and Processing of Satellite Sounding Data. Meteorological data are extremely perishable. Delays in data reception lead to considerable loss of forecasting skill. The previous discussion points out the need to observe large areas of the global atmosphere during specific time windows: within ±3 hours of the primary synoptic analysis times of 0000 Z and 1200 Z, and within ±3 hours of the secondary synoptic analyses times of 0600 Z and 1800 Z. The satellite observations must be relayed to the ground, then processed and delivered to the numerical forecast centers in time to be used in the numerical analyses.

At present, most of the sounding data from the two satellite systems are delivered to the National Meteorological Center (NMC) in time to be incorporated into the global analysis models for the four synoptic periods. This is accomplished by using a domestic communication satellite to relay data received at the Alaska and Virginia Command and Data Acquisition Stations (CDAs) to a Suitland, Maryland, processing center in near-real time. Data from the few "blind orbits" (orbits not in radio range of the two CDAs) are acquired by another CDA at Lannion, France, and are relayed via the GOES-East Data Collection System to the Virginia CDA for further relay to the data processing center at Suitland.

The present orbit of the afternoon satellite is planned to be moved to a 1330 local ascending mode beginning with NOAA H, in 1986. This will provide timely coverage over the Eastern Pacific to gather data vital for the Nested Grid (NG) analysis and forecast model. The NG is the primary forecast model for 12- to 48-hour forecasts of the weather over the continental United States. The proper analysis of weather systems that originate between 180° W. longitude and the west coast of the United States is critical to the accuracy of this model. These are the weather systems that will move eastward and affect U.S. weather in a 12- to 48-hour time period.

The change in the orbit time will permit the afternoon satellite to gather data over the Eastern Pacific, from the California coast to the dateline, between 0900 Z and 1200 Z on northbound passes. These data will be valid for the 1200 Z Limited-area Fine Mesh (LFM) analysis, which begins processing at 1350 Z. This means there is only 1 hour 50 minutes available to acquire and process data from the westernmost orbit (closest to 1200 Z), and to deliver the sounding product to NMC.

Similarly, the data from the southbound orbits must be acquired and processed between 2100 Z and 0000 Z to be available for the LFM analysis that begins at 0150 Z. A readout capability in Hawaii may be needed to provide timely acquisition of the data from these southbound orbits, as the data are acquired after the satellite passes over the Alaska CDA. After acquisition in Hawaii, these data could be relayed to Suitland either via GOES-West or by a commercial communications satellite. If this requirement for timely acquisition and relay to Eastern Pacific data is not met prior to 1990, it then becomes a NOAA K, L, M system requirements.

B. PROGRAMMATICS

1. DMSP

a. Multiyear Procurement (MYP). The following has been extracted from a DMSP MYP Congressional Exhibit extract:

The Air Force initiated a multiyear procurement of four DMSP spacecraft and sensors in FY83. Funding provided in FY83 and FY85 resulted in cost avoidance of $146.2M over annual buy contracts.

- Benefit to the Government: Provides a $146.2 million, 37.3 percent, cost avoidance. Provides an 85 percent probability of having the required satellites in orbit versus a 70 percent probability with four annual, fully funded contracts for one satellite each (tables II-1 and II-2).
- Stability of requirements: A requirement for DMSP satellites in orbit has persisted for 20 years. This requirement was recently (5 Oct 81) revalidated by the Joint Chiefs of Staff and is expected to remain unchanged during the contract period. Therefore, the risk of requirement changes is low.
- Stability of funding: Requirements for FY83-FY87 have been identified. The DMSP program office and the contractor have a good understanding of the required funding. The DMSP maintained a high priority during reviews of the FY83 budget, and has remained at a high priority in subsequent reviews. Therefore, the risk of funding instability is low.
- Stable configuration: The next four DMSP satellites will continue the Block 5D-2 configuration. These satellites will be substantially the same configuration as the five satellites previously procured. Therefore, the risk of configuration change is low.
- Degree of cost confidence: The multiyear proposal is based on fixed-price contractor proposals. The annual procurement estimate is based on a fixed-price spacecraft proposal, and a fixed-price primary sensor not to exceed estimate reduced by 25 percent (based on program experience). Therefore, the risk of cost estimating error is low.
- Degree of confidence in contractor capability: The spacecraft and primary sensor contractors (RCA and Westinghouse) have demonstrated their successful capability in

TABLE II-1

DMSP ACQUISITION STRATEGY COMPARATIVE SUMMARY

	Annual	Multiyear
Number of Units	4	4
Total Contract Price	391.8	245.6
Cancellation Liability (unfunded)	N/A	30.3
$ Cost Avoidance		146.2
% Cost Avoidance		37.3
Risk Related Factors		
–Requirement Stability	Low Risk	
–Funding Stability	Low Risk	
–Configuration Stability	Low Risk	
–Cost Confidence	Low Risk	
–Confidence in Contractor Capability	Low Risk	

TABLE II-2

SAVINGS AND COST AVOIDANCE

Quantity	FY 83	FY 84	FY 85	FY 86	FY 87	Total
Annual Contract Quantity	119.6 (1)	95.8 (1)	85.6 (1)	90.8 (1)	0	391.8 (4)
Multiyear Contract Quantity	149.0 (2)	0	96.6 (2)	0	0	245.6 (4)
Difference	+29.4	−95.8	+11.0	−90.8	0	−146.2

Source of Savings	Dollars in Millions
Vendor Procurement	115.3
Manufacturing	28.9
Design/Engineering	0
Tool Design	0
Support Equipment	0
Other	2.0
	146.2

their 20 years of manufacturing DMSP spacecraft and primary payloads. Therefore, the risk of contractor failure is low.

- Vendor procurement ($115.3 million): Most of the multiyear procurement savings result from the purchase of selected parts and subassemblies in economic order quantities. Using this approach, all parts required for the four primary sensors and spacecraft can be ordered during the first year, rather than four separate orders spread over 4 years. Savings result from lower prices for larger quantities, from avoiding gaps in vendor capability to provide required parts at stable prices, from avoiding costs of line recertification and quality testing on four separate lots, and lower costs for inspectors, quality control personnel, etc., since their work will terminate after the one delivery in the MYP.

- Manufacturing ($28.9M): Other multiyear procurement savings result from decreased labor in the production and testing of parts and subassemblies, since they will all be received/manufactured and tested at one time under the MYP.

- Other ($2.0M): A small part of the savings results from a more efficient use of the ground test equipment (AGE).

- Impact on defense industrial base:

  - No changes expected in competition, vendor skill levels, training, and progress payments.

  - Increased production capacity through more efficient allocation of manpower, equipment, and money.

  - Vendor multiyear contracts enabled the two prime contractors to buy selected parts and subassemblies from subtier vendors in the first year at efficient production rates of the subs.

  - Investment in more modern, automated test equipment was enhanced by producing four systems at one time versus one at a time, thus providing better equipment for the future production base.

b. DMSP Acquisition Strategy. The following is extracted from the DMSP Program Management Plan, Jan. 15, 1985:

- Satellite replenishment strategy: All DMSP efforts, including research and deployment, procurement, launch, and operation and support activities, are planned, budgeted, and managed to ensure that the required operational force structure of satellites is maintained in sun-synchronous polar orbit. With a requirement for continuous on-orbit coverage, DMSP acquires satellites with planned deliveries based on a forecast 10 percent need. DMSP requires 60 days for preparation and launch from satellite call up, plus an additional 30 days for early orbit check out. This assumes satellite storage at Vandenberg AFB, no launch pad conflicts or booster constraints, and no major problems. Mean Mission Duration (MMD), a parameter derived by evaluating the longevity of satellite subsystems, is used to predict the expected lifetime of DMSP satellites. A computerized General Availability Program (GAP) is used to predict the probability of need for a replacement satellite. It is a Monte Carlo simulation method analysis. GAP inputs include reliability data for the launch vehicle, satellite, solid rocket motor, ascent guidance software, and the probability of infant mortality for the first 6 months of satellite life. A truncation time also must be specified. Truncation for morning satellites is 42 months based on piece part irradiation, and 25 months for noon satellites based on battery expected life. GAP gives the projected 10, 50, and 90 percent probabilities of needing a replacement satellite. When the GAP is run, constrained by the actual contractual and/or programmed production schedule, probability curves can be generated that project satellite on-orbit availability over time. The probability of satellite availability given the current projected acquisition schedule is very close to 90 percent. However, due to budget constraints, inadequate satellite resources have been programmed to account for satellite attrition in light of a 17 percent probability of not achieving operational capability for each launch on Expendable Launch Vehicles (ELV). Satellite programming to account for attrition is essential. As past history has shown, it takes years to recover from a catastrophic failure.

- Future acquisition strategy: Initial DOD planning calls for an STS optimized, more survivable, and autonomous follow-on to the Block 5D-3 system (DMSP II), with increased payload capability to meet validated sensor requirements. A DMSP II cadre has been formed within the existing Program Office to begin concept development. DMSP II will be a competitive effort, beginning with four contractors for concept development in FY88. Current assumptions include:

  - Prime contractors (not separate for spacecraft and sensor).

  - Standardized Air Force Satellite Control Network (AFSCN).

  - Minimized impact to the user segment.

- The DOD could evolve DMSP II into a Defense Environmental Satellite System (DESS), which would perform all DOD environmental remote-sensing missions including, at a minimum, DMSP and Navy Remote Ocean Sensing System (N-ROSS).

DMSP acquisition strategy for production satellites is to request continued multiyear authority.

c. Planning, Programming, Budgeting System (PPBS). The following is extracted from HQ USAF PPBS Primer extract:

- PPBS description and characteristics: PPBS is the DOD resource management system. Controlled by the Secretary of Defense (SECDEF), its purpose is to identify mission needs, match them with resource requirements, and translate them into budget proposals. System outputs include the Defense Guidance (DG), the Five-Year Defense Plan (FYDP), and the DOD portion of the President's budget. The system is dynamic and evolves continually for many reasons, ranging from changes in key personnel to shifts in policy direction. One of the greatest single sources is the seating of a new political administration. Each new SECDEF adjusts the system to fit his style of management.

- National direction: There are a number of key documents in the annual cycle leading to the President's budget submission to Congress each January. National Security Policy provides the basis from which the defense guidance is developed. The Joint Staff and the Services also provide advice to the civilian defense authorities for their consideration during DG development.

  - National security policy is developed through the National Security Council (NSC) system and, when approved by the President, implemented by the National Security Decision Directives (NSDDs).

  - The NSC is the principal forum for considering international security issues requiring presidential decision. A committee structure consisting of senior interdepartmental groups (SIGs) and interdepartmental groups (IGs) supports the NSC.

  Each of the three phases of the PPBS, planning, programming, and budgeting, contributes toward attaining the ultimate objective--providing operational commanders with the best mix of forces and support attainable within fiscal constraints. Each phase overlaps the next (fig. II-2).

PLANNING

- Determine Total Forces Required to Counter Threat
- Establish Benchmark to
  - –Highlight Critical Needs
  - –Examine Risks
  - –Guide Resource Decisions

PROGRAMMING

- Match Available Dollars with Most Critical Needs
- Develop 5-Year Resource Proposal

BUDGETING

- Final Cost Approved Programs
- Prepare and Submit Detailed Budget
- Enact and Execute

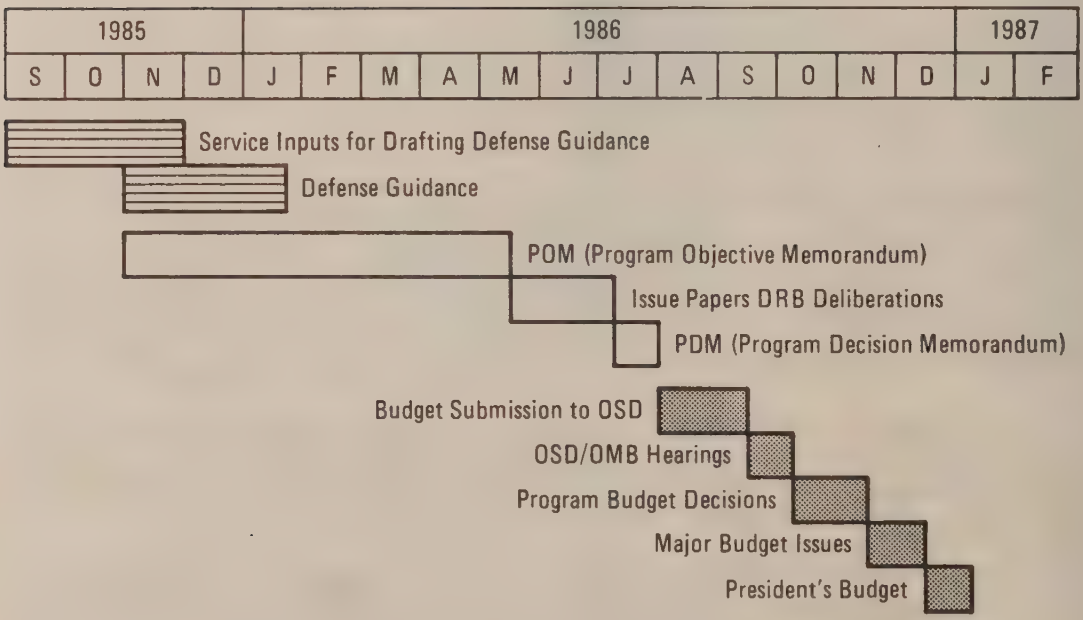


Figure II-2
Planning, Programming, and Budgeting System

- Planning: Identifies the threat facing the Nation during the next 5-20 years. Assesses U.S. capability to counter it, and recommends the forces necessary to defeat it. Planning highlights critical needs and examines risks if recommended goals are not attained in order to guide resource decisions.

- Programming: Matches available dollars against the most critical needs and develops a 5-year resource proposal. After this proposal is approved, it becomes the basis for budgeting action.

- Budgeting: Refines the detailed costs and develops the Service estimate required to accomplish the approved program. Following review and approval, it serves as the input to the President's budget. Budgeting plays a major role in defending the submission before Congress and executing Congressional appropriation legislation.

- PPBS sequence of events: Following is the general time phasing of key events within the PPBS for the FY85 President's budget.

  - Air Force planners started work in August 1981. During the next year, they developed items for internal Air Force use and provided inputs to the Joint Strategic Planning Document and the Defense Guidance.

  - The Defense Guidance is issued to the Services and the Joint Staff, and reflects the SECDEF's policy, strategy, force planning, resource planning, and fiscal guidance.

  - Program Objective Memorandum (POM) development is the intensive process by which the Services prioritize fiscally constrained program proposals for the next 5 years.

  - Issue papers are prepared by members of the Defense Resources Board (DRB) to suggest program changes to the service POMs. The DRB is the forum that reviews and provides recommendations to the SECDEF on these proposed changes to the Services' program.

  - The Program Decision Memorandum (PDM) records SECDEF decisions on the issues and directs adjustments to the Service POM.

  - The Budget Estimate Submission (BES) is the Services' budget proposal to the Office of the Secretary of Defense (OSD) on the POM, as updated by the PDM.

  - OSD and the Office of Management and Budget (OMB) hold hearings to gather supplementary information on how DOD arrived at specific budget estimates.

  - Program Budget Decisions (PBDs) issued by OSD are used to resolve most differences between Service BES and OSD/OMB pricing. Remaining major issues are resolved by the DRB and SECDEF.

  - The budget request, as approved by OSD and OMB, then becomes part of the President's Annual Budget Submission to the Congress (usually in January). Congressional review and (hopefully) approval occurs during the months prior to the start of the FY85 budget year (October 1, 1984).

  - One cycle totals 3 years from the start of Air Force planning until budget execution begins.

- Program Objective Memorandum (POM): The POM requires 6 months of concentrated effort each year to construct. It builds on the previous year's effort, expresses the Air Force Five-Year Program recommendations to OSD to meet the objectives of the Defense Guidance and the Air Force senior leadership, and identifies Air Force initiatives.

  - All major commands, separate operating agencies, and direct reporting units provide formal inputs.

  - Over 400 program element monitors (PEMs) provide inputs on over 600 AF program elements (PEs) that cover the entire AF program.

  - Special high national interest areas--like PEACEKEEPER, B-1, and space systems--undergo additional reviews.

  - Functional areas, which cut across mission areas and individual PEs, are reviewed to provide "more than one look" at the same item, so that decisions are made based on the most complete review possible.

The Director of Programs and Evaluation, as the Chairman of the Air Staff Board, is responsible for building the POM and justifying it during the subsequent program review process with OSD.

Functional staff and Major Commands (MAJCOMs) advocate programs and new initiatives throughout the process. MAJCOMs also review the POM at several points during its development. A key feature of the AF POM development process is the use of a corporate review body, the Air Force Board Structure, to bring it all together, to guide the development, and to provide recommendations to the Chief of Staff, Air Force (CSAF) and SECDEF.

2. POES

The NOAA polar-orbiting operational satellite system has been developed by NOAA and NASA in a cooperative program. Through the 1970's, and into 1980, NOAA was responsible for:

- Development of requirements
- Funding for operational systems
- Development and operation of ground receiving sites
- Development and operation of ground data processing systems
- Distribution of data to the users
- Archiving of data

NASA was responsible for:

- Development of spacecraft technology to include:
  - Design and production of protoflight instruments
  - Design and production of protoflight satellites
- Funding for protoflight instruments and satellites
- Production of operational satellites and instruments for NOAA on a cost-reimbursable basis
- Satellite launch and early orbit evaluation
- Engineering consultant services for NOAA

The NOAA polar-orbiting satellite system of the 1970's and 1980's has been designed around acquisition of data to meet the documented requirements of user agencies, as defined in the Federal Plan for Meteorology prepared by the Office of the Federal Coordinator for Meteorology. The defined requirements incorporated in this document were reviewed by NOAA and NASA, and those that could be met technologically, at a cost that the budget process could support, were accepted.

After the 1973 study, OMB directed NOAA to use the DMSP Block 5D Spacecraft Bus. Instrument design was to remain that which matched user requirements.

In 1983 NOAA considered changes to the polar system concurrent with planned system modifications required for the transition from the Atlas launch vehicle to what was thought would be a Space Transportation System (STS)-compatible satellite system. Before agreeing on a set of requirements that would form the basis for the NOAA K, L, M series, a steering group consisting of membership from NOAA [National Marine Fisheries Service (NMFS), Office of Oceanic and Atmospheric Research (OAR), National Environmental Satellite, Data, and Information Service (NESDIS), National Weather Service (NWS), National Ocean Service (NOS)], NASA, and DOD reviewed requirements, as well as a series of white papers that reviewed system tradeoffs. Here again, the accepted requirements considered technological capabilities and budgetary constraints.

Once system requirements have been accepted by NOAA, they are used to develop initial budgetary estimates that are eventually included in the request to the Congress for funding. In parallel, the requirements are provided to NASA, who uses them to develop a procurement package that includes a detailed in-house "grass-roots" cost estimate. This estimate is then used to modify the NOAA budget request, if required. The budget request is modified a second time, once signed contracts are available, to provide an improved estimate of total program cost and to establish a funding schedule to meet the contractor's estimate of the fiscal phasing of expenditures.

NOAA program management for the polar satellite program begins with the definition of requirements and continues through operation of the satellites in orbit. As previously mentioned, NOAA derives system requirements following careful review with the end product data users. From these requirements, NASA engineers develop the technical system specifications for system procurements. NOAA participates in all phases of the procurement, development, and launch of NOAA satellites. These functions are assigned to a NOAA/NESDIS liaison group that works with NASA during these phases of the program. This liaison group provides a day-to-day coordination mechanism for assuring that information flow between NASA and NOAA is smooth, and that diverse user requirements are weighted equally with technical aspects when engineering tradeoffs are required. This group participates in all phases of program planning with NASA, and helps to develop program positions on technical and financial matters. Members of the group are full voting members on Source Evaluation Boards, Technical and Business Advisory Committees, Performance Evaluation Boards, and design and launch readiness review committees.

NOAA budgeting for this program has been consistent with the NOAA/NASA agreement on shared funding for the program and the Office of Management and Budget (OMB) directive to use the DMSP-developed satellite bus. Through 1982, there was general agreement that NASA would fund the development of new instruments and satellites to meet the operational requirements of NOAA. It was a NOAA responsibility to fund follow-on satellite systems. NASA has now discontinued its support of improvements to the operational system, its last major effort being the development and flight of the protoflight Solar Backscatter Ultraviolet (SBUV) radiometer. NOAA now must fund all operational requirements, including the devleopment of advanced systems, such as the Advanced Microwave Sounding Unit (AMSU), and systems that must be changed for reasons over which there is no control, such as those associated with phaseout of the NASA ground tracking network and use of the Space Transportation System for satellite launchings.

The NOAA budget has undergone significant change since the first TIROS-N satellite was developed. Growth of the budget reflects not only technological growth but also the transfer of responsibility from one agency to another. Both inflation and program planning have limited satellite procurements to inefficient levels. It is interesting to note, however, that aside from cyclic effects, with aerospace inflation removed, the cost of the NOAA polar program is remarkably stable. System improvements and cost growth have been accompanied by reliability improvements that result in program economies, chief among which is longer satellite life. NOAA program management is cost conscious; a tight rein is kept on program requirements. A detailed report discussing the financial history of the NOAA program has been published as Envirosat-2000 Report, Analysis of Past Funding for NOAA's Satellite Programs (January 1985).

C. OPERATIONAL PROCEDURES

1. DMSP

a. Command and Control of On-Orbit Assets. DMSP command, control, and telemetry processing for the satellite is called the DMSP command, control, and communications (C^3) segment. The C^3, through its communications lines, provides all functions required to maintain the health and welfare of the DMSP satellites and provide communications to recover the meteorological payload data. These data are acquired during the satellite's 101-minute (nominal) orbital period. Although real-time meteorological data are supplied to transportable tactical terminals, access to the stored meteorological payload is obtained only when the satellite is within the station circle of one of the C^3 remote Command Readout Stations (CRSs). The maximum access period is approximately 15 minutes of each orbit. During this contact time, the C^3 segement must:

- Command the satellite in real time
- Provide the stored command inputs for satellite control when it is outside the station circle
- Analyze real-time engineering telemetry data
- Acquire orbital telemetry data for off-line trend analysis
- Provide communications for routing DMSP meteorological data to users

The C^3 segment makes use of several geographical ground station sites that operate as a whole to collect worldwide meteorological data from the DMSP satellites orbiting the Earth. The main sites, as shown in figure II-1, are:

- Site 1 (FAIR), at Fairchild AFB, Washington, and site 2 (LIZA), at Loring AFB, Maine. These two Command Readout Stations are used for direct uplink and downlink communications with the DMSP satellites. Each of the CRSs has two antennas, one for satellite tracking and the other for DOMSAT communication to AFGWC and FNOC.

- Site 3, at Offutt AFB, Nebraska. This site ingests and preprocesses the meteorological payload data for the atmospheric models on the computer systems at AFGWC.

- Site 4, at Vandenberg AFB, California. This Payload Test Facility (PTF) is used during prelaunch testing and launch phase for telemetry processing.

- Site 5, at Offutt AFB, Nebraska. The Satellite Operations Center (SOC) provides the planning, command/control, and equipment status telemetry (EST) processing required for spacecraft performance and health. The SOC provides a centralized communications center to all remote sites.

- Other Remote Tracking Stations (RTSs) can be linked to the C^3S through the Air Force's Satellite Control Facility (AFSCF) at Sunnyvale, California. These sites, though not dedicated to DMSP, are called into use from time to time if conditions require contact when an orbiting DMSP satellite is not within a CRS's circle. One of these stations, the Hawaii Tracking Station (HTS), has been upgraded with DMSP communications equipment to use a DOMSAT for data transmission.

- The FNOC in Monterey, California, uses the DMSP data to provide operational oceanographic products for the Department of the Navy.

- From the SOC, DMSP operational control is accomplished by transmitting command and load data to a CRS via DOMSAT. The CRS performs the real-time command and control of the DMSP satellite, the collection of telemetry and meteorological data from these satellites, and the relay of these data via DOMSAT to AFGWC and FNOC. The CRSs have the capability to simultaneously receive and record these data. Recorded data that are not relayed in realtime are retransmitted postpass. At AFGWC, the meteorological data, transmitted over DOMSAT from each CRS, are reconstructed and processed. A Data Reconstruction System (DRS) within AFGWC provides the capability to simultaneously record data for further processing, archival, hard copy generation, display of these data in real time, and input directly into the AFGWC processing facility. The composite telemetry payload data are sent to the SOC, where the EST telemetry data are separated for processing and analysis.

b. Communications Lines. The primary link from the SOC to the CRSs is via AMSAT CORP's WESTAR transponders. Command, telemetry, site status, command echo, and voice communication are transmitted over this link. Commands and telemetry are transmitted via the RF link to/from the DMSP satellites. DMSP data are transmitted from the CRSs and HTS to FNOC and AFGWC via WESTAR. Telemetry data from the HTS are relayed via a Defense Satellite Information System (DSIS) communications satellite to the SCF, then via land lines to the SOC.

These primary satellite links, operating on the frequencies shown on table II-3, are backed up by terrestrial lines that are capable of handling command and telemetry data, site status, and command echo data. Terrestrial lines do not provide backup for meteorological data communication to site 3. Additional terrestrial lines are provided for other remote sites including the PTF, AFSCF, and the DMSP Satellite Factory Site.

c. Data Aquisition. Refer to figure II-1.

Direct Readout.

- Downlink Frequency. 2252.5 MHz (SGLS Ch 11). Note: Direct data readouts can be transmitted through any of the other transmitters via payload data channel switching. The normal channel for direct data transmission is SGLS Ch 11.

Power:	5 W
Data Rate:	1.024 Mbps

- Readout Station. There are a total of 34 receiving terminals for direct data readouts from the DMSP satellites. They belong to USAF, USN, and USMC units. The USAF terminals consist of five fixed-site Mark IIA vans, eight Mark III fixed site vans, and four Mark IV transportable tactical terminal vans. The USMC component consists of seven Mark IV tactical terminals with five more planned. The USN has eight SMQ-10 receiving systems onboard aircraft carriers, and two TMQ-29 vans essentially the same as USAF Mark IIIs. Current USAF plans are to replace six Mark IIa and III vans with Mark IVs, and to upgrade the remaining IIa and IIIs with the advanced image generation and processing systems of a Mark IV (fig. II-3). Statistics are as follows:

TABLE II-3

DMSP COMMAND AND CONTROL COMMUNICATIONS FREQUENCIES

DMSP Uplink

L Band CRS/HPA – Frequency of 1792 MHz

DOMSAT Uplink Frequencies

Offutt to DOMSAT – 6104 MHz
FAIR to DOMSAT – 6174 MHz
LIZA to DOMSAT – 6198 MHz
HULA to DOMSAT – 6201 MHz

DOMSAT Downlink Frequencies

FAIR to Offutt/Monterey – 3957 MHz
LIZA to Offutt/Monterey – 3973 MHz
HULA to Offutt/Monterey – 3976 MHz

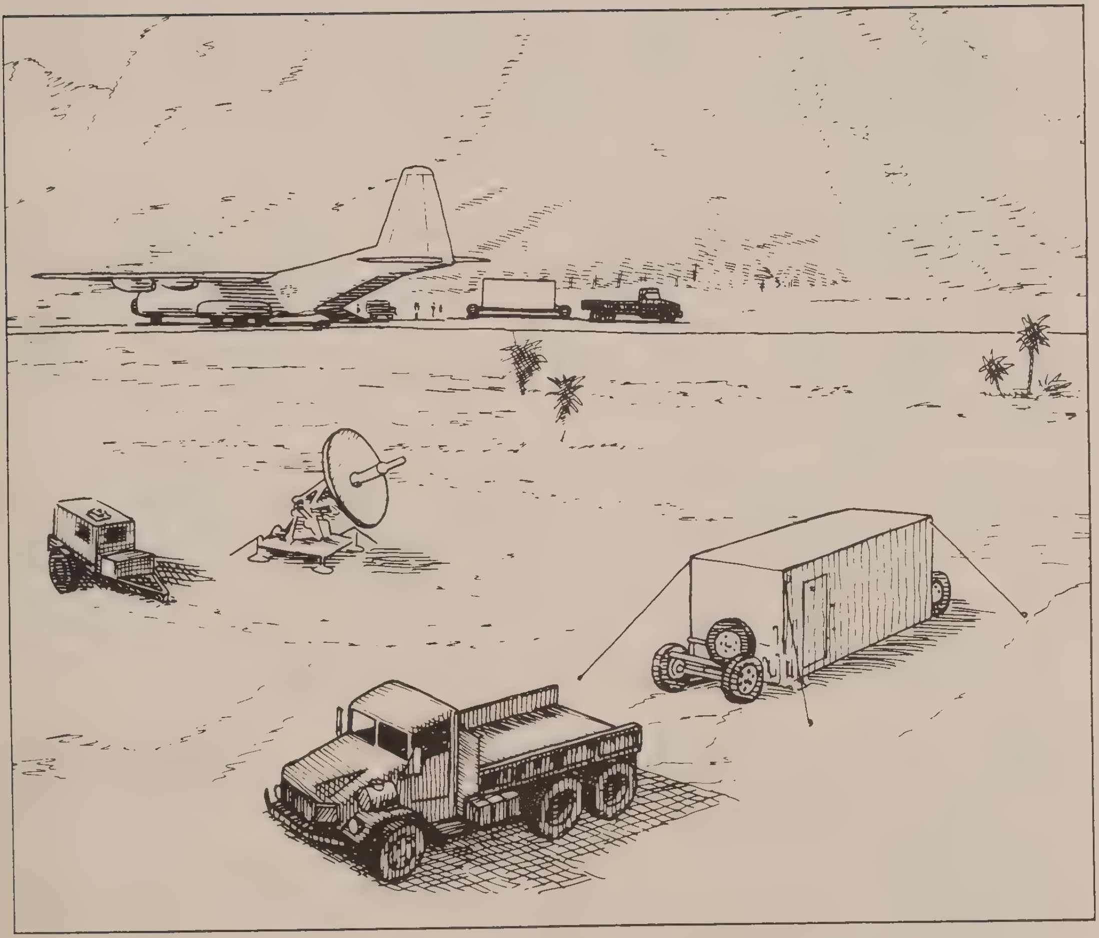


Figure II-3
Mark IV Tactical Van

  - Antenna size: 8-10 ft diameter, all terminal types.

  - Antenna type: Standard receive-only; Mark IIa/III/TMQ-29 are gimbal mounted and are high elevation restricted. Mark IV antenna can track high-elevation passes straight through. Mark IIa/III/TMQ-29 antennas are mounted on pedestals with radomes. The Mark IV antenna is deployable.

  - Ground equipment functions: Receive, process, display, and disseminate DMSP data. Mark IV uses a laser imaging system for printout. Others use wet film systems. Data are disseminated to attached supported operational forces.

  - Locations: See figure II-4 and table II-4.

- Data Types and Resolution. Data can be scanned in either IR or visible spectral bands. Real-time or direct data readouts send both types of data to the user. Normal resolution, or "smooth" mode, is 1.5 nmi (2.6 km). High resolution, or "fine" mode, is 0.3 nmi (0.55 km). The DMSP imager provides constant resolution over its total field of view.

  Direct data readouts can be sent either in a combination of visual fine/IR (or "thermal") smooth (LF/TS), or visual smooth/ thermal fine (LS/TF). The combination and area of coverage are dependent upon field unit needs. Also, DMSP data memory loads are used on a routine basis to advise each tactical site of the next pass of a DMSP or TIROS satellite. This is an important military capability to limit communications from deployed terminals.

- Direct Readout Data Processing. Mission sensor data, as well as the OLS data, are downlinked in the direct readout data stream. Currently, the mission sensor data are not used by tactical processing sites. In the future, the capability to process selected mission sensor data with the OLS data will be incorporated into tactical processing sites. For effective support to operational military commanders, it has proven essential to have an encrypted direct readout capability.

- Data Distribution.

  - Mark IIa and III: Positive transparencies are distributed to supported organizations either by a Satellite Imagery Dissemination System (SIDS) or by courier. The SIDS is composed of an anolog laser facsimile transmitter, located at the DMSP site, which is con-

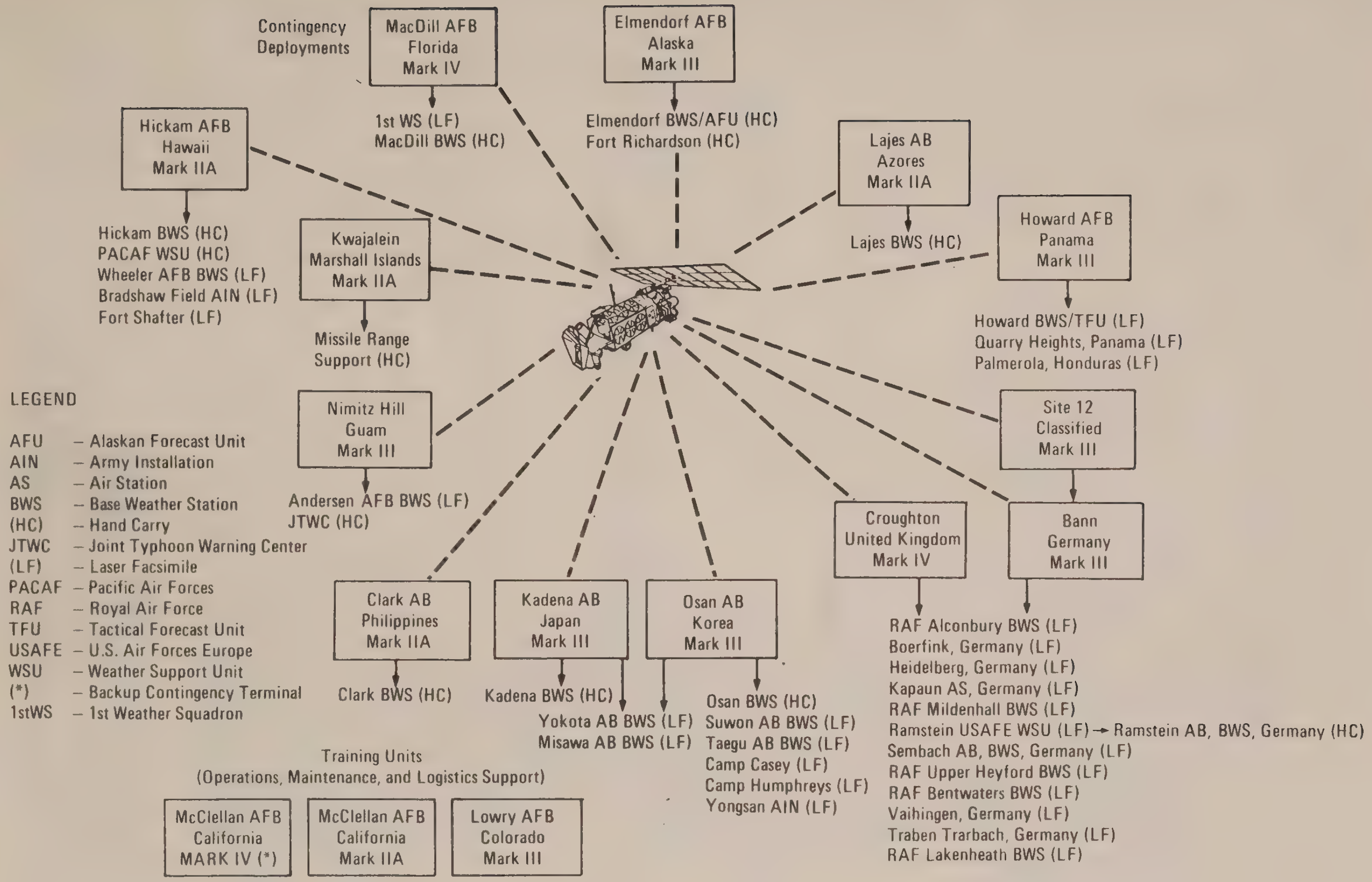

Contingency Deployments
MacDill AFB
Florida
Mark IV
1st WS (LF)
MacDill BWS (HC)
Elmendorf AFB
Alaska
Mark III
Elmendorf BWS/AFU (HC)
Fort Richardson (HC)
Hickam AFB
Hawaii
Mark IIA
Hickam BWS (HC)
PACAF WSU (HC)
Wheeler AFB BWS (LF)
Bradshaw Field AIN (LF)
Fort Shafter (LF)
Kwajalein
Marshall Islands
Mark IIA
Missile Range Support (HC)
Lajes AB
Azores
Mark IIA
Lajes BWS (HC)
Howard AFB
Panama
Mark III
Howard BWS/TFU (LF)
Quarry Heights, Panama (LF)
Palmerola, Honduras (LF)
LEGEND
AFU – Alaskan Forecast Unit
AIN – Army Installation
AS – Air Station
BWS – Base Weather Station
(HC) – Hand Carry
JTWC – Joint Typhoon Warning Center
(LF) – Laser Facsimile
PACAF – Pacific Air Forces
RAF – Royal Air Force
TFU – Tactical Forecast Unit
USAFE – U.S. Air Forces Europe
WSU – Weather Support Unit
(*) – Backup Contingency Terminal
1stWS – 1st Weather Squadron
Nimitz Hill
Guam
Mark III
Andersen AFB BWS (LF)
JTWC (HC)
Site 12
Classified
Mark III
Croughton
United Kingdom
Mark IV
Bann
Germany
Mark III
Clark AB
Philippines
Mark IIA
Clark BWS (HC)
Kadena AB
Japan
Mark III
Kadena BWS (HC)
Yokota AB BWS (LF)
Misawa AB BWS (LF)
Osan AB
Korea
Mark III
Osan BWS (HC)
Suwon AB BWS (LF)
Taegu AB BWS (LF)
Camp Casey (LF)
Camp Humphreys (LF)
Yongsan AIN (LF)
RAF Alconbury BWS (LF)
Boerfink, Germany (LF)
Heidelberg, Germany (LF)
Kapaun AS, Germany (LF)
RAF Mildenhall BWS (LF)
Ramstein USAFE WSU (LF) → Ramstein AB, BWS, Germany (HC)
Sembach AB, BWS, Germany (LF)
RAF Upper Heyford BWS (LF)
RAF Bentwaters BWS (LF)
Vaihingen, Germany (LF)
Traben Trarbach, Germany (LF)
RAF Lakenheath BWS (LF)
Training Units
(Operations, Maintenance, and Logistics Support)
McClellan AFB
California
MARK IV (*)
McClellan AFB
California
Mark IIA
Lowry AFB
Colorado
Mark III

Figure II-4
Air Force DMSP Tactical Facilities and Data Flow

TABLE II-4

DMSP TACTICAL TERMINAL LOCATIONS

MARK IIA Sites

1. McClellan AFB, CA
2. Hickam AFB, HI
3. Lajes AB, Azores
4. Clark AB, Philippines
5. Kwajalein Missile Range, Marshall Islands

MARK III Sites

1. Lowry AFB, Co (training facility)
2. Bann, Germany
3. Osan AB, Korea
4. Site 12: Classified
5. Elmendorf AFB, Alaska
6. Howard AB, Panama
7. Guam: [Joint Typhoon Warning Center (JTWC)]
8. Kadena AB, Okinawa

USAF MARK IV Sites

1. MacDill AFB, FL
2. Croughton, United Kingdom
3. McClellan AFB, CA
4. Harris Corporation, Melbourne, FL

USMC MARK IV Sites (Home Bases/Assigned to Deployable Marine Air Base Squadrons)

1. MCAS Cherry-Point, NC
2. MCAS New River, SC
3. MCAS Iwakuni, Japan
4. MCAS El Toro, CA
5. MCAS Futenma, Japan
6. MCAS Tustin, CA
7. MCAS Kaneohe, HI

DMSP Shipboard Terminals (SMQ-10) (CV, CVN Class Aircraft Carriers)

1. USS Constellation
2. USS Kitty Hawk
3. USS Midway
4. USS Independence
5. USS John F. Kennedy
6. USS America
7. USS Enterprise
8. USS Nimitz

NAVY Transportable Terminals (TMQ-29)

1. San Diego, CA
2. Rota, Spain

Note: 65 SMQ-11 Navy Ship and Shore Terminals in Development nected (via phone lines) to an unlimited number of receivers located at key command and control sites.

- Mark IV: Positive transparencies are distributed to supported organizations by a Tactical Imagery Dissemination System (TIDS). Contingency requirements necessitate that every Mark IV must have a dedicated TIDS. The system is composed of an analog laser facsimile transmitter, four receivers, and cabling to connect the system. The receivers can be deployed to nearby (400 m) locations to support key tactical command and control elements. Any additional number of receivers can be driven over phone lines at greater distances if communication lines and receivers are provided.

Stored Data Readout.

- Downlink Frequency: 2207.5 MHz (SGLS Ch 2)
  2267.5 MHz (SGLS Ch 4)

  Power: 5.5 W
  Data Rate: 1.33 Mbps or 2.66 Mbps

- Readout Stations. There are two DMSP CRSs: Fairchild AFB, Washington (FAIR), and Loring AFB, Maine (LIZA). In 1989 the Loring AFB CRS will be closed and replaced by an Advanced Remote Tracking System facility being installed by the AFSCF at Thule AB, Greenland, dedicated for DMSP use.

  The CRSs provide the radio frequency (RF) interfaces for the real-time command and control of the DMSP satellite, the collection of meteorological data from these satellites, and the relay of these data to the AFGWC and FNOC (fig. II-1).

  The two DMSP CRSs perform the direct uplink and downlink communications with the DMSP satellite. These sites receive, demodulate, record, reformat, multiplex, and transmit DMSP satellite data, via WESTAR, to processing equipment at the AFGWC and FNOC. The CRS functions primarily as a "bentpipe" uplink and downlink station for L-band frequency transmission to the satellite and S-band frequency reception.

  The uplink function of the CRS consists of receiving and reformatting command data from the SOC. The reformatted command is then modulated onto a carrier and amplified by the high-power amplifier located at the antenna feed.

The downlink function receives, stores, and forwards all incoming S-Band signals to AFGWC. As the S-Band signals are being received, a diode scanner connected to four S-Band dipoles (two for azimuth and two for elevation) is switched at 94-Hz rate. This provides antenna pointing error data (pseudomonopulse auto tracking) to the antenna positioning subsystem for continual tracking update to ensure accurate positioning during track. Antenna positioning is also computer controlled as backup. The S-Band (2.2 to 2.3 Ghz) received signal is translated within a downconverter to 300 to 400 MHz, and is routed to extract the real-time EST and stored meteorological data for store and forwarding. All data received from the satellite are recorded on tape recorders. This storage system allows post-pass playback in the event of communications outage. During the pass, the highest priority meteorological stream is forwarded via WESTAR to AFGWC and FNOC. The alternate data stream is retransmitted post-pass from the tape recorders.

- Data Types and Resolution.

Satellite	Imagery channels (micrometers)	Resolution (nmi)	Coverage frequency
DMSP	0.4 - 1.1	0.3 or 1.5 constant cross track	Global twice daily
DMSP	10.2 - 12.8	"	"

Note: 1.5 nmi resolution visible imagery is also available at night with 1/4 or more moonlight.

- Stored Readout Data Processing. AFGWC and FNOC are the primary users and distributors of DMSP satellite data. They receive, process, and disseminate the meteorological, oceanographic, and aerospace environmental data (forecasts, observations, and studies) required to support the Department of Defense (fig. II-5). AFGWC's site 3 reconstructs and processes data received real time and post-pass from each CRS. This DRS provides the capability to simultaneously record data for further real time and input data directly into the AFGWC computer complex.

  The DRS at site 3 receives the 3.072 Mbps baseband satellite data from the CRSs and the HTS. In addition, NOAA TIROS data are received on a 1.334 Mbps baseband satellite data line. The DRS processes and routes this received data in a real-time or playback mode to produce

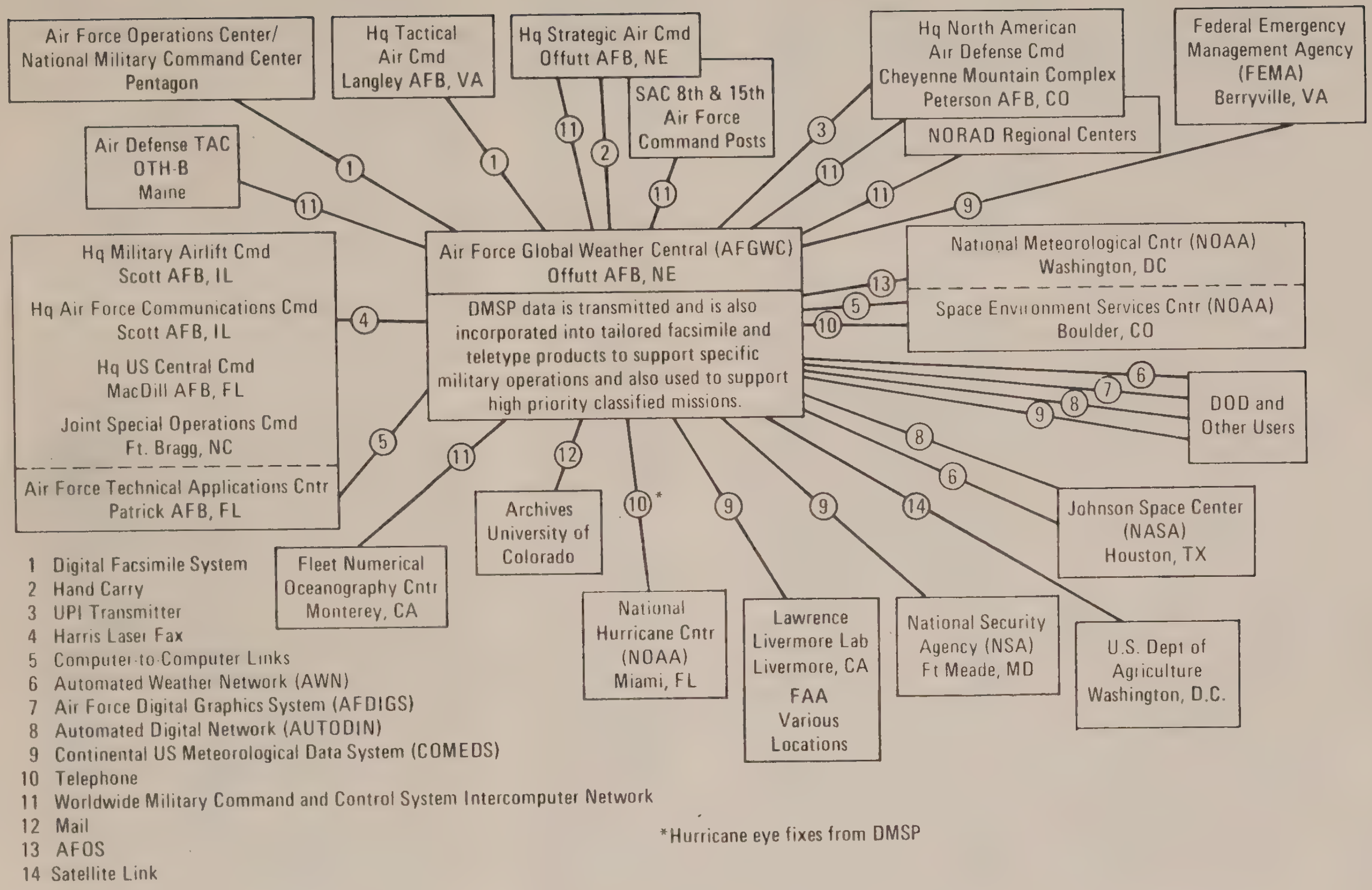

Air Force Operations Center/ National Military Command Center Pentagon
Hq Tactical Air Cmd Langley AFB, VA
Hq Strategic Air Cmd Offutt AFB, NE
SAC 8th & 15th Air Force Command Posts
Hq North American Air Defense Cmd Cheyenne Mountain Complex Peterson AFB, CO
NORAD Regional Centers
Federal Emergency Management Agency (FEMA) Berryville, VA
Air Defense TAC OTH-B Maine
Hq Military Airlift Cmd Scott AFB, IL
Hq Air Force Communications Cmd Scott AFB, IL
Hq US Central Cmd MacDill AFB, FL
Joint Special Operations Cmd Ft. Bragg, NC
Air Force Technical Applications Cntr Patrick AFB, FL
Air Force Global Weather Central (AFGWC) Offutt AFB, NE
DMSP data is transmitted and is also incorporated into tailored facsimile and teletype products to support specific military operations and also used to support high priority classified missions.
National Meteorological Cntr (NOAA) Washington, DC
Space Environment Services Cntr (NOAA) Boulder, CO
DOD and Other Users
Johnson Space Center (NASA) Houston, TX
Fleet Numerical Oceanography Cntr Monterey, CA
Archives University of Colorado
National Hurricane Cntr (NOAA) Miami, FL
Lawrence Livermore Lab Livermore, CA
FAA Various Locations
National Security Agency (NSA) Ft Meade, MD
U.S. Dept of Agriculture Washington, D.C.
1
1
11
11
2
11
3
11
11
9
13
5
10
6
7
8
9
8
6
4
5
11
12
10*
9
9
14
1 Digital Facsimile System
2 Hand Carry
3 UPI Transmitter
4 Harris Laser Fax
5 Computer-to-Computer Links
6 Automated Weather Network (AWN)
7 Air Force Digital Graphics System (AFDIGS)
8 Automated Digital Network (AUTODIN)
9 Continental US Meteorological Data System (COMEDS)
10 Telephone
11 Worldwide Military Command and Control System Intercomputer Network
12 Mail
13 AFOS
14 Satellite Link
*Hurricane eye fixes from DMSP

Figure II-5
AFGWC DMSP Data and Products Flow

hard copy photographic images, digital data streams (in a format acceptable to Sperry 1100 series computers), and telemetry data formatted for transmission to the C^3 at site 5.

The primary DRS equipment consists of magnetic tape recorders, data formatters, hard copy display devices, and a computer processing facility. During normal operations, the data are routed through the DRS equipment by computer-controlled switches. The DRS provides the site 3 operator with the capability to command the system via a keyboard, monitor these commands on a CRT, and monitor the system status on the oscilloscope. The DRS also provides voice communication capabilities with other site locations, as well as control of eight remotely located high-density tape recorders. The operator may request display of programmed data routing networks, command that the networks be implemented, or modify the networks via the CRT and associated keyboard. The operator may also request display of equipment status to determine the availability of each unit that may be used in a network. Manual control capability is also provided for start/stop functions of the data formatters, data routing from the data formatters to the Sperry 1100 series computers, and control of various functions on the hard copy displays.

2. POES

The current polar-orbiting spacecraft of the TIROS-N series have five separate instrument systems. They are the AVHRR, the TIROS Operational Vertical Sounder (TOVS), the DCS, the SEM, and the SBUV. This section describes the operational procedures by which the satellites are controlled and their data acquired for processing.

Data from the AVHRR instrument are available from the satellite in four operational modes. The first is direct readout of visible and infrared data to ground stations of the Automatic Picture Transmission (APT) class, worldwide, at 4 km resolution. Currently, there are more than 800 APT stations operating throughout the world, of which about 350 are government-owned facilities. The second mode is direct readout of the High Resolution Picture Transmission (HRPT), providing imagery worldwide at 1.1 km resolution (at nadir). HRPT ground stations have been established in the United States and many foreign countries. The third mode is global onboard recording of the 4 km-resolution data for commanded readout and processing in the NOAA computer facility in Suitland, Maryland. The fourth mode is onboard recording of data from selected portions of each orbit at 1.1 km resolution. These data are also centrally processed.

The TOVS system combines data from several complementary sounding instruments aboard the spacecraft: the HIRS, the Stratospheric Sounding Unit (SSU), and the MSU. The HIRS is designed to provide data that permit calculation of temperature profiles from the surface to the top of the Earth's atmosphere, water vapor content at three levels of the atmosphere, and total ozone content. The SSU provides stratospheric temperature information. This instrument is provided by the Meteorological Office of the United Kingdom. The third instrument, the MSU, provides microwave data that permit computations to be made in the presence of clouds, since microwave spectrum measurements are generally unaffected by clouds (although they are somewhat affected by precipitation cells).

The DCS onboard the TIROS-N series spacecraft is provided by the Centre National d'Etudes Spatiales (CNES) of France. It is known as the Argos data collection and platform location system, and is used to determine the location of free-floating buoy and balloon platforms. Additionally, it is able to acquire platform data from any place in the world, including the polar regions. The remote platforms transmit continually, and as the spacecraft passes within range of a platform, it receives and records the transmitted data. Once the spacecraft comes within range of a NOAA CDA Station (Wallops, Virginia, or Fairbanks, Alaska) it plays back the recorded data to the ground facility. On the ground, the data are forwarded to Suitland, where the Argos data are separated from other incoming spacecraft data and relayed to the CNES Processing Center at Toulouse, France. There, the platform locations are computed, and the data are prepared for relay to the appropriate users. Platform location can be determined to an accuracy of 5 to 8 km (3 to 5 mi).

The SEM instrument provides a continuous measurement of solar proton and electron flux activity near the Earth. The SEM also provides a measurement of the total energy distribution in the Earth's upper atmosphere. Data from the SEM are extracted from the data stream, combined with location parameters at the Suitland data processing center, and transmitted to NOAA's Space Environment Laboratory (SEL) at Boulder, Colorado. At the SEL, the TIROS-N data are used to monitor the state of solar activity, which has a significant effect on terrestrial communications, electrical power distribution, and high-altitude flight (e.g., Concorde SST and Space Shuttle).

The SBUV instrument is used to derive the distribution of ozone in the Earth's atmosphere. Using this information, NOAA can monitor the screening effect of atmospheric ozone and predict the intensity of ultraviolet energy reaching the

Earth's surface. This environmental parameter is important because of evidence linking ultraviolet radiation to skin cancer in human beings.

The TIROS-N series spacecraft are launched into near polar orbits at altitudes of about 850 km. The orbital period is about 102 minutes. In a two-polar spacecraft system, one satellite is launched into an "afternoon" orbit, which passes over the Equator (going north) at about 1430 local time. (This will be changed in the future; see chapter III of this report.) To provide greater global data coverage and redundancy against the unexpected failure of the primary afternoon satellite, the second satellite is launched into a "morning" orbit, which passes the Equator (going south) at about 0730 local time. Direct readout (APT and HRPT) stations are able to acquire at least two daytime passes and two nighttime passes from each spacecraft. The duration of data acquisition for each satellite overpass is about 12 minutes.

Spacecraft programming and commanding originates at the Satellite Operations Control Center (SOCC) in Suitland, Maryland. Commands, spacecraft telemetry, and environmental data are relayed between SOCC and the CDAs through a commercial communications satellite (RCA SATCOM). The CDAs communicate with the NOAA spacecraft using an S-band communications link, and read out the data stored on the satellite's digital tape recorders.

The TIROS-N ground system consists of two major subsystems: the Data Acquisition and Control Subsystem (DACS) and the Data Processing and Services Subsystem (DPSS). The DACS includes components at the two NOAA CDA stations, SOCC, the Western European Station (WES) in Lannion, France, and the Satellite Field Services Station (SFSS) in San Francisco, California. (See chapter III, section E for a description of command and control of payload, and chapter VII for a description of the Lannion support.) All of the DPSS components are at the NOAA facility in Suitland.

The DACS includes all components necessary to command and control the spacecraft, to monitor its "health" via housekeeping telemetry, and to retrieve and transmit the spacecraft environmental data to the DPSS processing and data handling facility. Delivery of TIROS-N data from Wallops and Fairbanks to Suitland is accomplished using the commercial satellite communications network. This system, which includes Earth stations at Gilmore, Wallops, and Suitland, delivers the data to SOCC at a 1.3 Mbps data rate. The data are then passed to the DPSS for processing.

Each day there are three or four consecutive orbits for which each spacecraft is out of range of both NOAA and CDA stations. To eliminate the resultant time delay in the receipt of the high-priority sounding data during this "blind" period, the Western European station at Lannion, France, was established jointly by the United States and France. This station acquires the stored sounding data and transmits them to the United States via the eastern GOES satellite at 75° W. longitude. Use of this additional readout station reduces the periods when the TIROS-N satellite is out of contact with the ground to a maximum of one orbit per day.

The DPSS ingests, preprocesses, and stores the raw satellite data, along with appended auxiliary information such as Earth location and quality control parameters. This subsystem consists of several segments of high-speed computers, intermediate disk storage units, and a mass data storage system. Initially, this mass storage was accomplished using the AMPEX Terrabit mass storage system. In early 1985, NESDIS began replacing the Terrabit Memory (TBM) as part of a new DPSS subsystem consisting of an IBM 4381 multiprocessor system operating in a multiprogramming mode. This system provides computing resources for both polar and geostationary ground operations, and for time sharing, data base, communication, and batch processing services. The multiprocessor system will consist of one IBM 4341 and three IBM 4381 mainframes, with a total of 32 million bytes of directly addressable memory. The peripheral complex will consist of six magnetic tape drives and sixteen 3380 disk units, for a total capacity of 40 billion bytes, an automated switching management system, eight cartridge tape drives for archival use, and a front-end communications controller capable of handling up to 100 communications lines.

The new system initiated polar operations in April 1985; geostationary processing will be integrated into the system in early 1986. At that time, NESDIS will have an integrated, multiprocessing polar and geostationary computer system containing a single hardware and software architecture that can be readily expanded as future requirements may dictate.

D. FIT WITH OTHER AGENCY PROGRAMS

1. DMSP

The mission of the DMSP is to provide, through all levels of conflict, global visible and infrared cloud data, and other specialized meteorological, oceanographic, and solar-geophysical data required to support worldwide DOD operations and high-priority programs. Timely data are supplied to the

AFGWC, the FNOC, and deployed tactical receiving terminals worldwide. While the primary mission of DMSP satellites is gathering weather data for military uses, data gathered by the satellites are routinely provided to the civilian community through NOAA for use in a backup and supplemental data role.

The Operational Linescan System (OLS) is the primary sensor aboard the spacecraft providing visible and infrared imagery. The imagery is used to analyze cloud patterns in support of a wide range of military requirements from photomapping to issuing severe weather warnings. A passive microwave temperature sounder (SSM/T) provides data for profiling atmospheric temperatures on a global basis from the Earth's surface to altitudes above 30 km. A precipitating electron spectrometer (SSJ/4) is used to determine the position of the auroral boundary, thereby aiding radar operations and long-range ground communications. A gamma/x-ray detector (SSB) has provided data on x-rays and electron density profiles for specialized Air Force applications.

a. Use of Products Generated From the OLS Data. The OLS imagery is the data source for the Satellite Global Data Base (SGDB) at AFGWC. The SGDB is used as primary input into the AFGWC real-time nephanalysis model and in building hard copy photographic-quality display images. These products permit support to detection and monitoring of major weather systems; location and intensity estimation of hurricanes and typhoons; creation of three-dimensional cloud analysis for numerous applications; discrimination of cloud and snow; computation of soil moisture and an index of vegetation growth; and the detection of hot spots caused by volcanic eruptions. The primary users of OLS data are:

DOD. Global cloud imagery is used by military weather forecasters to detect and monitor developing weather patterns and follow existing weather systems. The data help identify severe weather such as thunderstorms, determine the location and intensity of tropical cyclones, and form three-dimensional cloud analysis of various weather conditions. The automated global cloud analysis performed at AFGWC is used as input to their global numerical cloud forecast models.

The FNOC uses DMSP imagery along with sea surface temperature data in its global ocean forecasting program. The imagery assists in interpreting the location and intensity of oceanic extratropical cyclones for quality control prior to initialization of numerical forecast models. Navy tactical sites (primarily aircraft carriers) use DMSP imagery to provide insight into atmospheric and oceanographic processes occurring in their operational areas. In addition to observing existing weather systems, various aspects of sun glint and anomalous gray shade patterns permit determination of sea state, low-level wind direction, atmospheric moisture, sea surface temperature gradient, and oceanic fronts and eddies.

NOAA. DMSP imagery is routinely provided to NOAA for use in a backup and supplemental data role. As backup, the global cloud imagery will be used by the National Meteorological Center to prepare global analyses of weather patterns, as well as to support the National Hurricane Center in monitoring and locating tropical cyclones. NOAA may also use the DMSP imagery to produce snow cover maps primarily for estimating snowpack in watersheds. DMSP cloud imagery is also available to the civil and research community through the data archives (see chapter XIII). NESDIS is the archival agency for OLS data. Imagery of 0.3 and 1.5 nmi resolution dating back to 1973 are archived at the National Snow and Ice Data Center (NSIDC) at the University of Colorado in Boulder. Also archived are 3 nmi-resolution mosaics compiled from several orbits dating back to 1975. In addition to DMSP cloud imageries, auroral photographs from the DMSP operational linescan system are archived at the World Data Center A, University of Colorado.

Department of Agriculture (USDA). Cloud patterns from DMSP imagery, along with snow cover charts, are used by AFGWC's Agromet models to compute global soil moisture. This soil moisture information is provided to USDA for calculating a Vegetation Index to monitor global agriculture patterns and conditions.

b. Use of Products Generated From the SSM/T Data. Soundings produced from SSM/T data consist of atmospheric temperatures for 15 pressure levels, corresponding layer thicknesses, and the temperature and pressure of the tropopause. Height contours are derived at AFGWC by summing individual retrieved layer heights and adding a forecast 1,000 mbar height.

DOD. The vertical temperature profiles provided by the SSM/T data supplement conventional data in creating the Upper Air Data Base (UADB) at AFGWC. The UADB provides the input for automated analysis models such as the High-Resolution Analysis System (HIRAS) and the Point Analysis Model. The output from HIRAS initializes all of the numerical prediction models used by AFGWC to produce global and regional forecasts. These numerical analyses and forecasts support global Air Force and Army strategic and tactical operations along with other specialized applications.

NOAA. SSM/T data are used by NESDIS to develop the operational capability to process SSM/T soundings at NESDIS for Shared Metsat Processing. The quality and accuracy of SSM/T temperature retrievals are evaluated in conjunction with the development of the operational processing capability.

c. Use of Products Generated From the SSJ/4 Data. The Precipitating Electron Spectrometer provides precipitating electron flux to determine the location of the auroral boundary.

DOD. The SSJ/4 data supports Air Force operations that require knowledge of the state-of-the-polar and high latitude ionosphere, namely communications surveillance, and detection systems propagating energy off or through the ionosphere.

NOAA. NESDIS is the archival agency for SSJ/4 data and provides auroral data to the civil and research community.

d. Use of Products Generated From the Shared Processing Agreement. As Shared Meteorological Satellite Data Processing (see chapter X) is implemented, the three national environmental centers of expertise will assume the following primary data processing responsibilities and provide that data to the other agencies: AFGWC, cloud imagery; FNOC, oceanographic data; NOAA/NESDIS, atmospheric soundings.

Under this concept, each of the processing centers will have access to, and will integrate into its ground data processing, raw sensor data from both NOAA and DMSP spacecraft. For example, NESDIS will produce and distribute, for operational use, sounding products produced from the DMSP microwave temperature sounder (SSM/T), in addition to producing soundings from NOAA's TOVS. NESDIS also plans to integrate data from the DMSP microwave imager (SSM/I), which will be flown in 1986, into the operational sounders program to improve the overall quality of the products. SSM/I data will permit the calculation of new parameters such as surface type, land surface temperature, soil moisture, rain rate, precipitable water, snow water content, cloud amount, and ocean surface wind speed. Common to all operational centers will be an effort to provide backup assistance to each other in the event of a failure somewhere in the ground or space segments. Backup operations will provide data continuity and will assure the continuation of product generation and delivery.

DOD. The impact on DOD of new parameters provided by the SSM/I data will be tremendous. The following are the perceived operational applications of SSM/I parameters.

AFGWC. Ice coverage will provide background brightness field to assist in automated cloud analysis and forecasting. Precipitation rate will assist in tropical cyclone analysis and forecasting, support Army trafficability and engineering concerns, provide input to agricultural impact (AGROMET) models, and assist in analyzing communications attenuation. Cloud water content and cloud amount will provide input to cloud analysis and forecast models, as well as cloud-free line-of-sight information for operation of aircraft and electro-optical systems. Surface moisture data will be used for AGROMET models and support to Army trafficability assessment. Water vapor content will provide an expanded data source for cloud analysis models and for initializing numerical forecast models. Water vapor analysis will also provide a correction factor to apply to data obtained from space-based sensors operating in the infrared (IR) and microwave bands. Land surface temperature will be used by the cloud analysis model for cloud-no cloud decisions, and by the AGROMET models for computing the soil moisture index. Surface temperature information will also be used to support rescue operations, soil trafficability, river stage and flood forecasts, and contingencies involving the dispersion of chemical and nuclear agents. Snow parameters (like ice coverage mentioned above) will provide background brightness fields to assist in automated cloud analysis and will provide input to the AGROMET models. Forecasts of soil trafficability, river stage, flood, and air rescue conditions also depend on snow information.

FNOC. Ocean surface wind speed will assist in routing ships, computing wave generation and sea state, and determining wind distribution around tropical cyclones. Wind speed will also be used to support ship refueling and aircraft operations, and as input to an ocean noise estimation model. Ice parameters will assist in planning and executing polar operations and in ship routing and iceberg avoidance. Precipitation rate will assist in the analysis of severe weather features such as fronts and tropical cyclones. This additional information will aid ship routing and aircraft operations and will be used for input to the ocean noise model. Cloud water content will aid aircraft operations and electro-optical systems support. Water vapor content along with cloud water content will permit detection and forecasting of vertical gradients of refractive indices, and atmospheric transmission affecting a variety of systems including communications, missiles, surveillance vehicles, infrared and electro-optical weapon systems, and tactical support missions. Water vapor analysis on a synoptic scale will be used to initialize numerical forecast models, and will provide a correction factor for data such as sea surface temperature estimation obtained from space-based sensors operating in the IR and microwave bands.

NOAA. NESDIS will process SSM/I data under the shared processing concept, and will integrate the data into the operational program to improve the overall quality of the sounding data. SSM/I-derived parameters will be used to correct interpretation of satellite observations from other IR and microwave sensors. For example, rainfall, cloud water content, and water vapor content adversely affect sea surface temperature estimation and temperature profiles.

Additionally, NOAA, NASA, FAA, and civil agencies use various DMSP data and products (fig. II-5).

2. POES

The principal data base serviced by the NOAA polar-orbiting satellites is the NWS numerical forecast data base. However, other agencies share in the use of these data, and in some cases unique products appropriate to other agency needs are generated as an adjunct to the primary observing mission. The NOAA polar satellites carry instruments to carry out the following functions:

- AVHRR - view the Earth in both the visible and infrared (thermal) spectra
- TOVS - sound many layers of the atmosphere
- SBUV - measure the ozone layer in the atmosphere
- SEM - measure the solar proton flux and energy distribution at spacecraft altitude
- Argos - provide data collection and location services in cooperation with the Centre National d'Etudes Spatiales of France
- SARSAT - provide search and rescue services in a cooperative effort with France, Canada, and the Soviet Union
- APT, DSB, HRPT - provide direct data transmission services

Various agencies use all forms of the NOAA data for atmospheric, oceanic, solar, climate, and agriculture programs. These programs use both real-time and archived data.

a. Use of Products Generated From the AVHRR Data. The AVHRR data are a major source for objective image analyses and quantitative data products on a global basis. These data provide support to marine interests, shipping, and off-shore industries. They allow users to measure snow and ice concentrations; compute an index of vegetation growth and dispersion; detect hot spots caused by volcanic eruptions, brush and forest burning; detect major weather patterns; and monitor and locate tropical disturbances. The major users are:

NOAA. Global cloud depiction maps of both day (visible) and infrared (day and night) cloud cover are used by the NMC to prepare global analyses of weather patterns. The data are particularly useful over the oceans and in the Southern Hemisphere, where conventional meteorological data are extremely sparse.

The sea surface temperature (SST) data base is available to NWS and NMC. Detailed sea surface temperature analyses are used for locating thermal boundaries indicative of fish concentrations, analyzing and forecasting sea fog, and locating major current boundaries. Between 20,000 and 40,000 observations of sea surface temperature are produced each day from the two polar satellites, with the number of observations varying with cloud cover.

Monitoring of global weather on a daily basis is essential for evaluating abnormal weather events around the globe. The data provide a climatological record for analyzing long-term trends affecting the global weather.

Snow cover maps are used for estimating snowpack in watersheds to predict spring melt in support of flood forecasting and water resource management. Global climate monitoring is obtained from estimating measurements of the balance of incoming (solar) and outgoing (Earth) radiation. A record of the global net radiation budget is derived from plots of regional cooling and warming determined with the five spectral channels of the AVHRR. This record provides climatic analyses and assessments upon which to base long-term outlooks of monthly and seasonal climatic changes.

DOD. Imagery from the AVHRR is used as a primary backup and source of supplemental data by the DOD. The AFGWC at Offutt AFB, Nebraska, and the FNOC in Monterey, California, are the principal data centers that routinely acquire the NOAA satellite data. The AFGWC includes the imagery data in its objective 3-D cloud analyses, which are input to their global numerical cloud prediction models, and prepares tailored mapped projections of the imagery for special applications. FNOC includes the AVHRR imagery and sea surface temperature data in its global ocean forecasting program.

Image data concerning cloud cover, weather patterns, and sea surface conditions are acquired from the real-time direct broadcast systems using mobile surface receiving stations located aboard all Navy carriers, and selected amphibious ships and flagships.

The Naval Polar Oceanography Center-Navy/NOAA Joint Ice Center (JIC) in Suitland, Maryland, uses the AVHRR imagery in analyzing ice conditions over the ocean areas and the Great Lakes. These analyses are shared with NOAA facilities.

USDA. The USDA uses the AVHRR image and thermal data coupled to form vegetation indices to monitor global agriculture patterns and conditions. Cloud patterns indicating rainfall and snow cover charts are used to monitor crop moisture patterns on a global scale.

Coast Guard. The Coast Guard relies on cloud pattern analyses to determine weather conditions in search and rescue operations, and depends on ocean current and temperature data to estimate drift of ships in distress and the odds of in-water survival. Imagery is particularly useful in the Arctic areas, where sea ice and severe weather combine to hamper rescue operations.

NASA. The image data are used to provide cloud cover analyses in support of space shuttle missions. AVHRR data are also used in support of atmospheric, oceanic, solar, climate, and agriculture research programs. Also, cloud and precipitation estimates are made from the AVHRR images in support of deep space probe readout operations.

b. Use of Products Generated From the TOVS Data. The TOVS system is composed of the HIRS/2, the SSU, and the MSU. The HIRS/2 is the primary instrument providing the calculation of vertical temperature profiles, water vapor content at three levels of the atmosphere, and total ozone content. The SSU instrument provides temperature information in the stratosphere. The MSU instrument is used in conjunction with the HIRS/2 infrared sounder to permit atmospheric sounding computations to be made in the presence of clouds.

TOVS operational products include mean temperatures for 40 atmospheric layers from the surface to 1 mbar at about a 50 km resolution and precipitable water amounts for three layers of the atmosphere from the surface to 700 mbar, 700 to 500 mbar (10,000 to 18,000 ft), and above 500 mbar (18,000 to 30,000 ft). To reduce errors in the analyses, the individual soundings are clustered to provide observations every 250 km. Approximately 600 sounding observations are generated in each orbit. The two satellites produce about 16,000 soundings per day about the globe. The major users of the sounding products are:

NOAA. The quantitative data describing the vertical structure of the atmosphere provide an essential input for the global analyses of weather patterns. These analyses form the initial conditions for the numerical weather prediction models used by the NMC to produce global and hemispheric forecasts ranging from 12 hours to 10 days. The accuracy and usefulness of these forecasts are directly dependent upon the accuracy of the knowledge of the beginning state of the atmosphere from which the forecasts are made.

DOD. The TOVS data are used in the numerical forecasting models at both AFGWC and FNOC. The AFGWC numerical analyses and forecasts are primarily for support to global Air Force operations, tactical and strategic target forecasts, and other specialized applications. FNOC uses the data for oceanographic and weather support to global naval operations and ocean state analyses.

Foreign Users. Atmospheric soundings produced by NOAA are distributed on an orbit-by-orbit basis worldwide by the international weather circuits, collectively called the Global Telecommunications System (GTS), operated by the WMO. The unprocessed SSU data are transmitted directly to the British Meteorological Service; the sounding observation data base, as prepared for NMC, is transmitted every 3 hours to both the British Meteorological Service at Bracknell, U. K., and the European Centre for Medium-Range Weather Forecasts (ECMWF) nearby. The satellite-derived soundings are an essential element of the ECMWF extended forecast model.

c. Use of Products Generated From the Space Environment Monitor (SEM). The SEM measures solar proton flux, electron flux density and energy spectrum, and total particulate energetic particle flux at spacecraft altitude. The two detectors included within this instrument are the Total Energy Detector (TED) and the Medium-Energy Proton and Electron Detector (MEPED). This instrument augments the measurements made by NOAA geostationary satellites. The SEM data are sent to NOAA/ERL, Boulder, Colorado, for use at the Space Environment Services Center.

NOAA and the USAF jointly operate a solar-environmental monitoring facility at Boulder, Colorado. SEM data from the NOAA satellites are used to monitor and predict solar events, such as sunspots and flares, and their effects on the magnetic field. Measurements of arriving energetic particles are used to map the boundaries of the polar auroral ovals, which affect ionospheric radio communications, over-the-horizon radar systems, electric power distribution systems (particularly in the higher latitudes), and manned space activities such as space shuttle flights. Archived data are available for research on solar-atmospheric interaction, sponsored by NASA, NSF, and other agencies (e.g., NASA forecasts of radiation hazards for prolonged space flights).

d. Use of Products From the Data Collection and Platform Location System. The data collection and platform location system is provided by the CNES of France at no cost to the United States. The French have named this the Argos data collection and platform location system. The Argos provides a means to locate and collect data from moving and fixed platforms (drifting buoys, balloons, etc.) at the time of the data transmission, using Doppler techniques. (See chapter VIII for detailed information on the Argos system.)

Argos data are combined with the spacecraft telemetry beacon data, which are continuously transmitted to the Earth while being concurrently stored on board the spacecraft recorders for later transmission during the spacecraft data transmissions to CDA stations. Data acquired by the NOAA Command and Data Acquisition stations at Wallops, Virginia, and Fairbanks, Alaska, are relayed to the Suitland, Maryland, processing center, where the unprocessed Argos data are separated and forwarded to the CNES for processing and location determination prior to distribution to users of the data. The Argos also relays in situ observations of surface meteorological and oceanic conditions. The successive locations of moving platforms measure drifts caused by ocean surface currents (ocean buoys) and mid- or upper-level winds (balloons). The platform location capability also has been used to track the movement of oceanic vessels and marine animals in research programs. Uses by various agencies include the following:

NOAA. The relay of in situ environmental data from platforms in the Arctic and Antarctic provides vital inputs to analyses of weather patterns transiting the Arctic regions before they affect the United States. Drifting buoys and weather balloons are used by NOAA in major oceanic and atmospheric observational research programs. Such programs include NOAA's participation in the WMO's First Global Atmospheric Research Program (GARP) Global Experiment (FGGE), and GARP Atlantic Tropical Experiment (GATE) research programs. Sea surface temperatures relayed by the fixed and moving ocean platforms provide in situ observations that are used to calibrate the SST data computed from the AVHRR data.

Coast Guard. The U. S. Coast Guard places buoys in regions where currents are expected to carry icebergs into shipping lanes. Also, transmitters placed on bergs aid in tracking the berg positions.

DOD. While the Navy does not operate Argos-equipped buoys, it benefits from the Argos service in ocean regions where Argos buoys are located. Since Argos data are delivered via the GTS, they become available to all meteorological users, including FNOC. About 75 buoys currently report conditions along the U. S. west coast from California to Alaska. Another 20 are deployed in the Atlantic, and a smaller number in the Gulf of Mexico.

Foreign Users. Weather data from the 500 drifting buoys deployed during the FGGE in the Southern Hemispheric oceans proved valuable to forecasters in Australia, New Zealand, southern Africa, and South America. Over half of these buoys are still returning useful data. Western Europe is also discussing using drifting buoys as partial replacements for North Atlantic weather ships.

e. Use of Products From Search and Rescue (SAR) Data. The Search and Rescue (SAR) system is a cooperative program involving France, Canada, the Soviet Union, and the United States. U. S. agencies participating include NOAA, NASA, the USAF, and the Coast Guard. The satellite instrument receives and relays signals from emergency transmitters on aircraft and ships. Local User Terminals (LUTs) process data received directly from the satellite, and provide central search and rescue centers with the location of activated emergency transmitters. Two Soviet polar-orbiting satellites now carry instruments that are interoperable with the SAR instrument carried on NOAA satellites. See chapter VI for further details of the system.

The roles of the various participating agencies in the SAR program are as follows:

DOD. The USAF operates the Mission Control Center (MCC) and Rescue Control/Coordination Center (RCC) at Scott Air Force Base, Illinois, and Elmendorf AFB, Alaska (NOAA will take over the MCC function in 1988). The Air Force coordinates search and rescue missions for downed aircraft in the inland United States and Alaska.

Coast Guard. The Coast Guard operates RCCs in their 10 Districts to coordinate marine rescue missions.

Foreign. Spaceborne equipment for the SAR mission is provided by Canada and France. These relationships will continue through the decade, with Canada and France continuing to provide hardware. See chapter IX for more details about international aspects of the SAR program.

f. Continuous Data Transmission Capabilities. In addition to the satellite transmission capabilities needed by NOAA to command the satellites, monitor the condition of onboard systems, and transmit data to NOAA facilities for central processing, there are three communication systems used extensively by groups outside of NOAA and the United States. These are the Automatic Picture Transmission, the High Resolution Picture Transmission, and Direct Sounder Broadcast systems. These systems are of special interest, particularly to DOD and foreign users.

Automatic Picture Transmission (APT). The APT system consists of two very high frequency (VHF) transmitters (for redundancy), one of which broadcasts continuously. Ground receivers are equipped to operate at either of two frequencies used by the system. There are well over 1,000 APT receiving stations throughout the world, with over 600 of these outside the United States. Data being collected over the local area are acquired by these ground stations while radio contact is maintained with the satellite. The APT broadcasts two of the AVHRR spectral channels at 4 km resolution. The image scan is stretched horizontally to remove the panoramic distortion caused by the scan geometry from space. Such data are intended for viewing local weather conditions. Users of the APT service are:

- NOAA. APT capabilities are no longer required to fulfill the domestic program responsibilities of the NWS. However, NOAA supports WMO efforts to establish APTs in developing countries. NWS Overseas Operations has placed at least 40 APTs in countries overseas under the WMO/Voluntary Cooperative Program. ERL is beginning to use APT for field support. Other NOAA research programs, some involving R/Vs at sea, occasionally use these capabilities.

- Other Federal Agencies. The Bureau of Reclamation supports APT use in Africa for weather modification. The Coast Guard uses APTs on some of their icebreakers.

- Nonfederal and Foreign. In the United States at least 50 academic institutions have an APT receiver; over 200 are planned; five commercial and 350 hobbyists currently have active APTs. Overseas, government agencies, at least 120 academic institutions, 15 commercial firms, and 200-500 amateurs have operating APTs. By far the most important are the foreign government stations, which, in many developing countries, provide the only up-to-date weather information.

- DOD. APT is used by Navy, Marine, Air Force, Air National Guard, and Army field elements for tactical support because the receiving equipment for APT is relatively unsophisticated, inexpensive, and highly mobile.

High Resolution Picture Transmission (HRPT). The NOAA polar-orbiting satellites carry three S-band transmitters. Two of these are dedicated to transmitting data to NOAA's CDA stations. The third provides redundancy for CDA transmissions, and also serves as the HRPT transmitter, which continuously transmits all AVHRR data in realtime to any ground station equipped to receive the digital signal. Users of this more sophisticated system include:

- NOAA. In addition to the two CDAs (Fairbanks and Wallops Station) NOAA operates an HRPT in Redwood City, California for weather and oceanographic support. NOAA's

National Marine Fisheries Service in Boston is part of a consortium (Northeast Area Remote Sensing Service) of government and academic organizations installing HRPTs to support the fisheries industry and other coastal activities.

- DOD. There are 24 DMSP tactical terminals operated by the U. S. military forces that can receive HRPT data.

- Other Federal Agencies. The National Science Foundation funds, and the Navy supports, an HRPT station in the Antarctic; the Scripps Institution of Oceanography, under a government contract, uses their HRPT for oceanographic research.

- Nonfederal. Since HRPT stations may cost well in excess of $200,000, few are privately operated. In the United States, two are operated by HRPT hardware manufacturers, and one each by the Universities of Wisconsin and California.

- Foreign. HRPT, like APT, is used extensively in other nations. There are nearly 70 stations owned by 43 countries. Canada has five, Germany four, Brazil, France, Norway, and Sweden two each, and commercial units are located in Canada and Italy. Universities in Germany have two stations, and one more is operated by a university in the United Kingdom. Most government-owned units are found in Europe, plus a few in Africa (Tunisia, Tanzania, South Africa), Southeast Asia (Indonesia, Malaysia, New Zealand), and Asia (Mongolia, Korea, China, and Japan).

Direct Sounder Broadcast (DSB). Direct Sounder Broadcast services are derived from the TOVS instruments. Data from the instruments, when processed on the ground, provide a detailed profile of atmospheric temperature and humidity.

Analysis of the TOVS data requires very sophisticated computer processing. Until 1980, only four DSB stations were receiving and analyzing TOVS data; today 20 stations in 16 countries process the data. Three more countries plan to establish this capability. Two universities and one commercial company overseas are among those processing, or planning to process, DSB data. The rest are all government agencies.

The DSB uses the real-time telemetry data stream developed for the normal spacecraft beacon transmissions. The DSB is thus a no-cost result of this data flow architecture.

Shared Processing Agreement Between NOAA and DOD. In 1984, NOAA and DOD implemented a shared processing agreement to distribute the ground processing of data from both the DMSP and NOAA meteorological satellites and future Navy oceanographic satellites across major operational processing centers. This agreement was initiated to minimize operational duplication while maintaining a high degree of backup between centers. AFGWC will process and map all of the visible and infrared imagery, FNOC will process all oceanographic data products, and NOAA will process all of the atmospheric sounding data from the constellation of environmental satellites. Domestic communications satellite links are used to distribute the output products in realtime to the computers in each of the processing centers. Shared processing in this manner provides mutual access to the AFGWC, FNOC, and NOAA data bases. Also, data continuity is assured in the event of a spacecraft or ground processing failure. A more detailed description of the shared processing activity is provided in chapter X.

III. TECHNICAL COMPARISON

A. BUS COMPARISON

The modern TIROS and DMSP spacecraft buses are very similar, and are based on the 5D-1 spacecraft, which RCA developed in 1972 after winning a competitive procurement. Figure III-1 provides a view of these satellites. Note that the major difference in the bus is the length of the equipment support module, which was stretched from 137 to 183 cm. The spacecraft payloads are unique because of the different mission requirements. As the programs evolved, the commonality among the buses was maintained, providing significant economic benefits to the government.

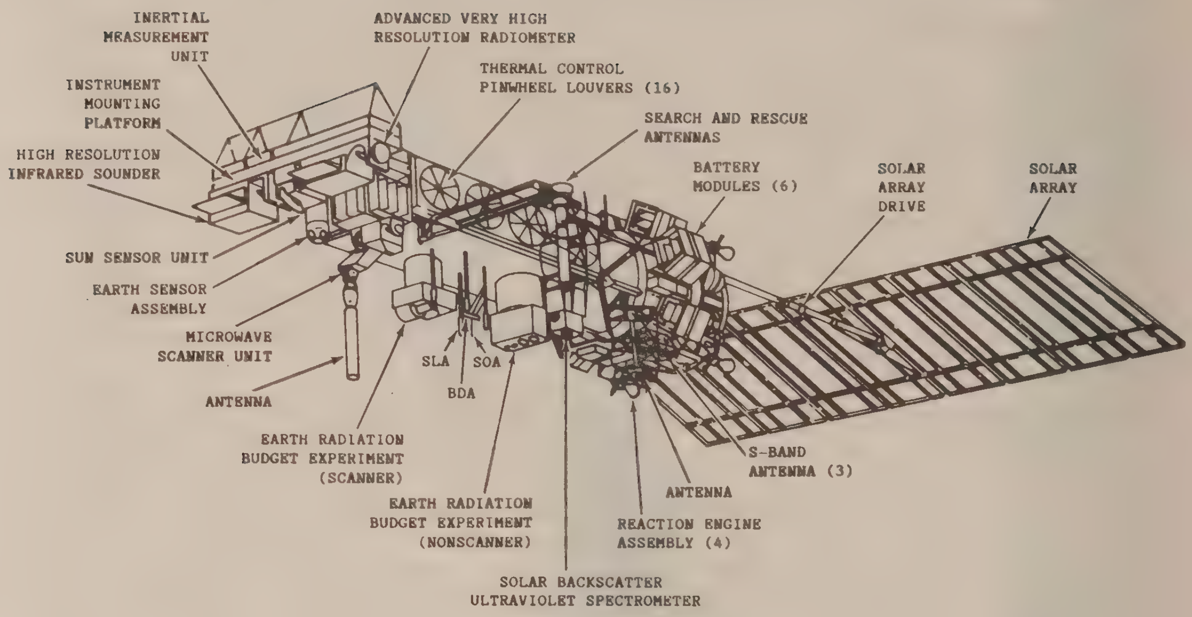
The POES was developed subsequent to the DMSP 5D-1 spacecraft bus competition in 1972. NOAA, in 1974, decided to utilize the same bus for the next-generation POES (designated as TIROS-N). As a consequence, RCA received a fixed price, sole source contract for eight such spacecraft. Concurrently, the Air Force recognized that the 5D-1 was a relatively small spacecraft (46 cm shorter) and joined with NOAA in sponsoring a stretched version of the 5D-1, for TIROS-N and 5D-2. NOAA funded the development test program and the lengthening of the solar arrays. The Air Force funded the structural design. Tables III-1 and III-2 show a side-by-side comparison of the spacecraft buses, beginning with 5D-1, and their evolution, including a brief summary of their features.

The government has, as a result of the bus commonality in the civilian and military programs, realized substantial economies because of design cost sharing, economies of scale in procurement, and the transfer of "lessons learned" between the programs.

1. DMSP

RCA Astro-Electronics is the prime contractor to the Air Force for the Integrated Spacecraft Segment (ISS) of the overall DMSP system. The purpose of the ISS is to place its orbiting stage, together with the sensors and data processing payload (satellite), into a 833 km, sun-synchronous orbit, and thereafter to provide power, attitude control, thermal control, command, and communications services to the payload for a 4-year mission lifetime. The Block 5D-2 satellite utilizes a sophisticated two-computer configuration as part of a general purpose Command and Control subsystem. This approach has been extremely successful in providing orbital needs, and has demonstrated significant benefits by extending operating lifetimes

POES


INERTIAL MEASUREMENT UNIT
ADVANCED VERY HIGH RESOLUTION RADIOMETER
THERMAL CONTROL PINWHEEL LOUVERS (16)
INSTRUMENT MOUNTING PLATFORM
SEARCH AND RESCUE ANTENNAS
HIGH RESOLUTION INFRARED SOUNDER
BATTERY MODULES (6)
SOLAR ARRAY DRIVE
SOLAR ARRAY
SUN SENSOR UNIT
EARTH SENSOR ASSEMBLY
MICROWAVE SCANNER UNIT
SLA
SOA
BDA
ANTENNA
EARTH RADIATION BUDGET EXPERIMENT (SCANNER)
EARTH RADIATION BUDGET EXPERIMENT (NONSCANNER)
S-BAND ANTENNA (3)
ANTENNA
REACTION ENGINE ASSEMBLY (4)
SOLAR BACKSCATTER ULTRAVIOLET SPECTROMETER

DMSP

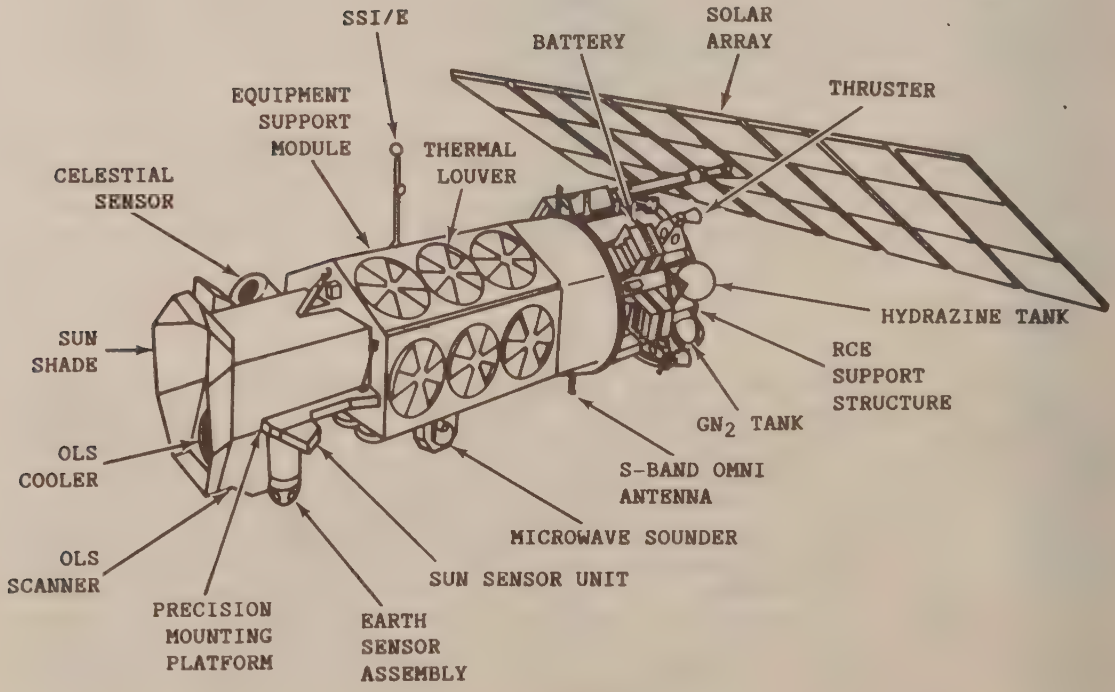

SSI/E
BATTERY
SOLAR ARRAY
EQUIPMENT SUPPORT MODULE
THRUSTER
THERMAL LOUVER
CELESTIAL SENSOR
SUN SHADE
HYDRAZINE TANK
RCE SUPPORT STRUCTURE
GN2 TANK
OLS COOLER
S-BAND OMNI ANTENNA
MICROWAVE SOUNDER
OLS SCANNER
SUN SENSOR UNIT
PRECISION MOUNTING PLATFORM
EARTH SENSOR ASSEMBLY

Figure III-1
POES/DMSP System Overview

Table III-1
DMSP/POES System Descriptions and Differences

SUBSYSTEM	DMSP	POES
-Orbit Required Average Alt.	833 ± 18.5 km	833 ± 18.5 km and 870 ± 18.5 km
Inclination	98.7 ± 0.15	98.8 ± 0.15
Apogee-Perigee	55.56 km max.	55.56 km max.
In-Orbit Mass	752 - 840 kg	1039 kg
● SOFTWARE SUBSYSTEMS		
-AGS	Designed for 833 km - has soft separation from Atlas - commands deployables and asserts proper orbit	Very similar, and in some cases identical, code as DMSP - 833 and 870 km versions
-ADACS Software	Contains PAS for 0.01 pointing	No PAS, 0.1 pointing control loop modified for new inertias
-Command and Control	Processes real-time and stored commands	Similar to DMSP
-Executive	Autonomous control	Similar to DMSP spacecraft
● COMMUNICATIONS SUBSYSTEMS		
-Data Transmitters	Five 5-W solid-state, high-efficiency S-band transmitters. Frequencies of 2207.5,2237.5(2), 2252.5,2267.5 MHz	Three 5-W units (1695-1710 MHz)
-Receiver Demodulator Unit (RDU)	Redundant receivers with dual SGLS compatible. Demod (1791.748 MHz)	VHF unit at 148 MHz. Handles SGLS format command

Table III-1 (continued)

SUBSYSTEM	DMSP	POES
● COMMUNICATIONS SUBSYSTEMS - continued		
-VHF Telemetry Beacon	Not used	Two (redundant) 1-W beacon transmitters (136-138 MHz)
-APT Data Transmitter	Not used	Two (redundant) 5-W APT transmitters (136-138 MHz)
-Antennas	4 directional S-band 1 pair omni S-band 1 pair omni L-band	3 directional S-band 3 near omni VHF 2 directional VHF
● COMMAND AND CONTROL SUBSYSTEM		
-Central Processing Unit (CPU)	Low power, miniature computer with 32K of R/W RAM memory. 2 used for redundancy. Bottom 8K readdressable 2-bit fault detection 1-bit fault correcting	Same as for DMSP except no readdressability
-Controls Interface Unit (CIU)	Multiple board, hard-wired logic unit to interface between computers and all other spacecraft components	Similar to DMSP, some boards common, others unique
-CIU Annex (CXU)	Not used	Extension of CIU commands
-Signal Conditioning Unit (SCU)	High-power switching circuits and relays (ordnance firing, deployment releases, mag. coil drive, etc.)	Similar to 5D-2, but 5-board unit instead of 6-board (no second stage separation)
-Redundant Crystal Oscillator (RXO)	Redundant, high-stability clock source for spacecraft	Same as for DMSP

Table III-1 (continued)

SUBSYSTEM	DMSP	POES
● DATA HANDLING SUBSYSTEM		
-Collects and Formats Telemetry Data	Programmable Information Processor (PIP)	Telemetry information processor (TIP), similar to PIP but nonprogrammable
-Vibration Sensors (VS)	3 piezoelectric devices for vibration sensing during ascent	Not used
-MIRP	Part of OLS payload	MIRP algorithms for data processing and compression
-Tape Recorders	4 digital tape recorders, each with 1.67 x 10^9 bit capacity	5 digital (DTR) tape recorders, each consisting of two 4.5 x 10^8 bit capacity tape transports
● ATTITUDE DETERMINATION AND CONTROL SUBSYSTEM (ADACS)		
-Inertial Measurement Unit (IMU)	4 HI MOD-MIG gyros and 3 Sundstrand accelerometers. Self-contained thermal control 10 Hz clock out external	Same as DMSP
-Celestial Sensor Assembly (CSA)	6 detectors, static star sensor. Solid-state silicon	None required
-Earth Sensor Assembly (ESA)	4 COU2 band IR horizon sensor groups (static). Pitch and roll determination	Same as DMSP
-Reaction Wheel Assembly (RWA)	Miniature, high-speed (10,000 rpm max.), PWM-driven torquer. 3 orthogonal units plus one in skew orientation for redundancy	Same as DMSP

Table III-1 (continued)

SUBSYSTEM	DMSP	POES
-Pitch (PTC) and Roll/ Yaw Coils (RYC)	Magnetic momentum unloading coils	Larger coils
● POWER SUBSYSTEM		
-Solar Array (SA)	11.6 sq m solar cell array with integral shunt power limiters made up of 8 hinged panels for folded stowage during ascent S 8, 9 & 10 use high eff. solar cells	Same as DMSP except use high efficiencies cells
-Solar Array Drive (SAD)/ Array Drive Electronics (ADE)	Single axis motor for SA rotation with integral slip ring power transfer assembly. Drive electronics has two modes--coarse gain and fine gain for greater torque disturbance correction	Similar to DMSP, no fine gain mode
-Batteries	2 17-series cell nickel cadmium rechargeable batteries. Independent disconnect relays for redundancy management	3 17-cell 26.5 batteries
-Power Supply Electronics	Redundant +28 volt central regulator and mode controller. 5 channel PSE on some	5 channel PSE
-Power Converter (PC)	Redundant +5 volt logic level voltage regulator	Same as for DMSP
-Battery Charger Assembly (BCA)	Dual battery charger control electronics	Increased capability
● PROPULSION SUBSYSTEM		
-Reaction Control	4 N_2H_4 445 newtons engines, 8 N_2 8.9 newtons motors, with tankage	Same as DMSP

Table III-1 (continued)

SUBSYSTEM	DMSP	POES
	For 15.9 kg N_2H_4 and 2.3 kg N_2 bi-direction isolation valve in N_2 manifold. All welded--No "B" nuts	
-AKM (GFE)	Thiokol 364-15 SRM weight: 703.7 kg	Same as DMSP
● STRUCTURE SUBSYSTEM		
-RCE Support Structure (RSS)	Cylindrical RCE and -AKM support	Identical to DMSP except for unique wire harnessing connectors stronger
-Equipment Support Module (ESM)	5-sided dog house-shaped module (alum. honeycomb panels on aluminum frame to titanium truss)	Lengthened 46 cm additional louver
-Sensor Mounting Platform	Precision mounting platform (PMP) brazed alum. section platform. Ball joint isolated from ESM; thermally isolated from instruments to maintain precision alignments	Instrument mounting platform (IMP) larger T-shaped plate. Open cell construction to allow louver thermal control
● THERMAL SUBSYSTEM		
-Radiators, Louvers, Shields	Variable emissivity radiators by means of bimetallic actuated trapdoor and pinwheel louvers. Multilayer blanket shields	Similar techniques
-Thermal Control Electronics (TCE)	Pulse width modulated heater controller for louvers or make up heaters	Same as for DMSP

Table III-1 (concluded)

SUBSYSTEM	DMSP	POES
● LAUNCH VEHICLE (GFE)		
-Booster	Atlas E (ground-controlled radio guidance)	Atlas E
● SPACECRAFT ASCENT PHASE EQUIPMENT (APE)		
-Heat Shield	2.1 m diameter metal(furnished as GFE)	Same as DMSP. TIROS-N RF transmission accommodated by special design modifications to heat shield. Operations frequencies different from DMSP. 56 cm longer
-Booster Adapter	Cylindrical portion supports heat shield. Conical section supports satellite	Conical adapter supports orbital stage. Similar but stronger

Table III-2
DMSP/POES Weight Summary

SUBSYSTEM	DMSP 5D-2 (kg)	POES (kg)
Structure	122.04	203.3
Thermal	22.93	43.0
ADACS (dry)	57.89	55.7
Power	129.84	163.0
Communications	7.99	25.1
Command and control	26.33	27.7
Data handling	10.31	16.4
Harness	40.68	72.3
GFE payload	134.25	265.8
GFE growth	35.78*	65.5
AKM case	48.12	48.1
Balance	96.16	32.7
S/C margin	35.00	10.0
S/C dry	767.32	1028.7
N_2H_4	17.21	17.2
GN_2	2.41	2.4
AKM expendables	664.66	664.1
S/C at lift-off	1451.60	1712.3

*Mission sensors

because of the reprogrammable flexibility of the system. This capability has been used to work around spacecraft component failures or degradation, and to reconfigure the system.

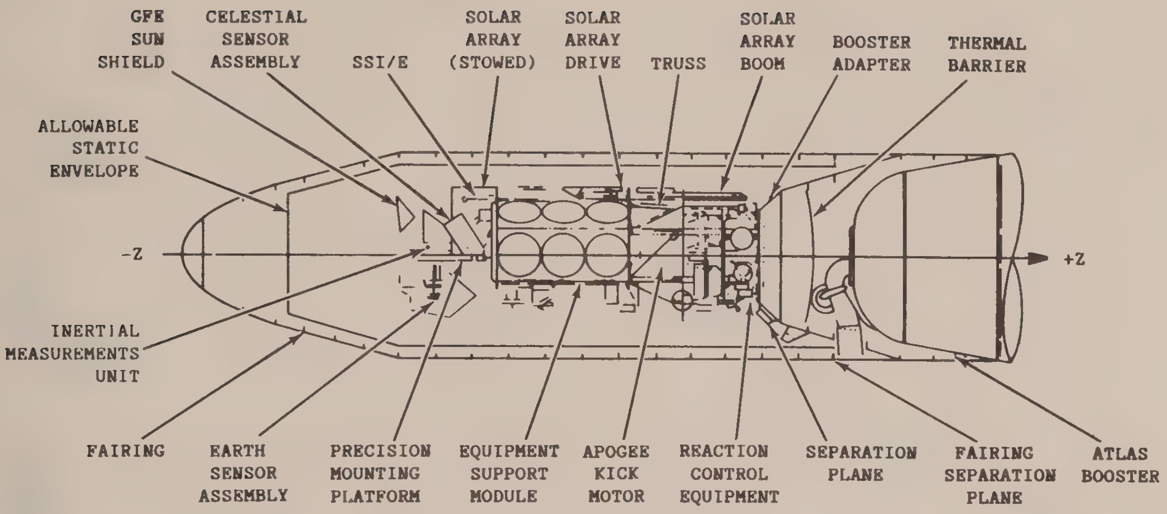
a. ISS. The ISS is composed of a booster adapter and an Apogee Kick Motor (AKM) located in the satellite, all enclosed within a heat shield assembly as shown in figure III-2. For launch, the solar array is folded around the orbital stage. The adapter mates to the first stage booster, an Atlas E/F. At lift-off from the launch pad, the ISS weighs 2,656 kg, of which approximately 840 kg represents the orbital satellite (fig. III-3).

The ISS ascent, orbit injection, and solar array deployment phases are shown in figure III-4, which also lists the sequence of events for a nominal trajectory. During ascent, the heat shield, the booster, and its adapter are jettisoned after Booster Engine Cutoff (BECO). The satellite, which contains the reaction control equipment and spent AKM, is inserted into a circular, sun-synchronous, near-polar orbit at an altitude of 833 km. The ascent trajectory is shown in figure III-5.

During ascent and orbit injection, the solar array is folded against the ESM and held in this position by two retaining bands. The Glare Obstructor (GLOB) for AM orbits and the SSI/E mission sensor boom are also held against the ESM by restraining mechanisms.

Once the satellite is in its approximate mission attitude, the GLOB phase 1 deployment is initiated, which allows the GLOB to swing out into alignment with the +X axis, but with the shade still folded. The solar array bands are then released by firing redundant pyrotechnic devices, and the array starts to deploy. First, the eight array panels unfold to a coplanar position, driven by spring-loaded hinges. The array boom is then rotated 180°, carrying the coplanar array with it, and locked in place. Finally, the array is canted to the proper angle and locked in place, ready to rotate to track the sun. The entire deployment sequence requires approximately 8 minutes.

After array deployment is completed, as shown in figure III-3, the long axis (Z) is oriented to the orbit normal. The attitude control system keeps the spacecraft X axis pointed at the Earth continuously around the orbit, while a single axis drive keeps the solar array looking at the sun. During the GLOB phase 2 deployment, the GLOB unfolds into its orbital configuration.


GFE SUN SHIELD
CELESTIAL SENSOR ASSEMBLY
SSI/E
SOLAR ARRAY (STOWED)
SOLAR ARRAY DRIVE
TRUSS
SOLAR ARRAY BOOM
BOOSTER ADAPTER
THERMAL BARRIER
ALLOWABLE STATIC ENVELOPE
-Z
+Z
INERTIAL MEASUREMENTS UNIT
FAIRING
EARTH SENSOR ASSEMBLY
PRECISION MOUNTING PLATFORM
EQUIPMENT SUPPORT MODULE
APOGEE KICK MOTOR
REACTION CONTROL EQUIPMENT
SEPARATION PLANE
FAIRING SEPARATION PLANE
ATLAS BOOSTER

ISS Launch Configuration

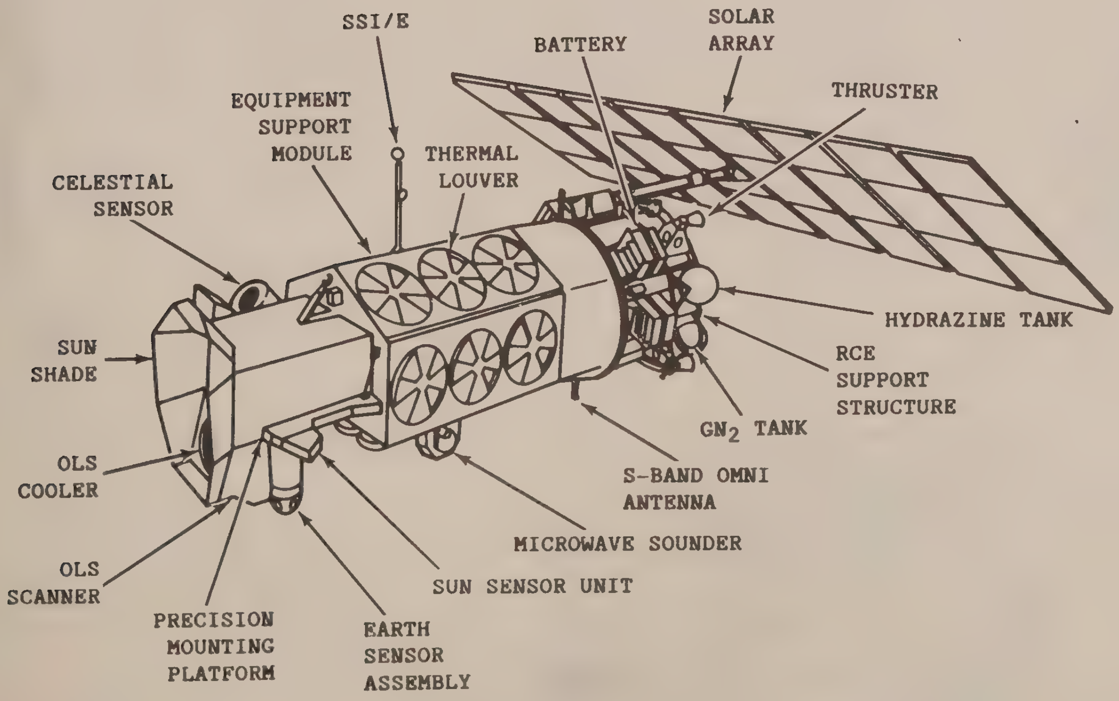

SSI/E
BATTERY
SOLAR ARRAY
THRUSTER
EQUIPMENT SUPPORT MODULE
THERMAL LOUVER
CELESTIAL SENSOR
SUN SHADE
HYDRAZINE TANK
RCE SUPPORT STRUCTURE
GN$_2$ TANK
OLS COOLER
S-BAND OMNI ANTENNA
MICROWAVE SOUNDER
OLS SCANNER
SUN SENSOR UNIT
PRECISION MOUNTING PLATFORM
EARTH SENSOR ASSEMBLY

Figure III-2
Orbital Configuration of a Block 5D-2 Satellite

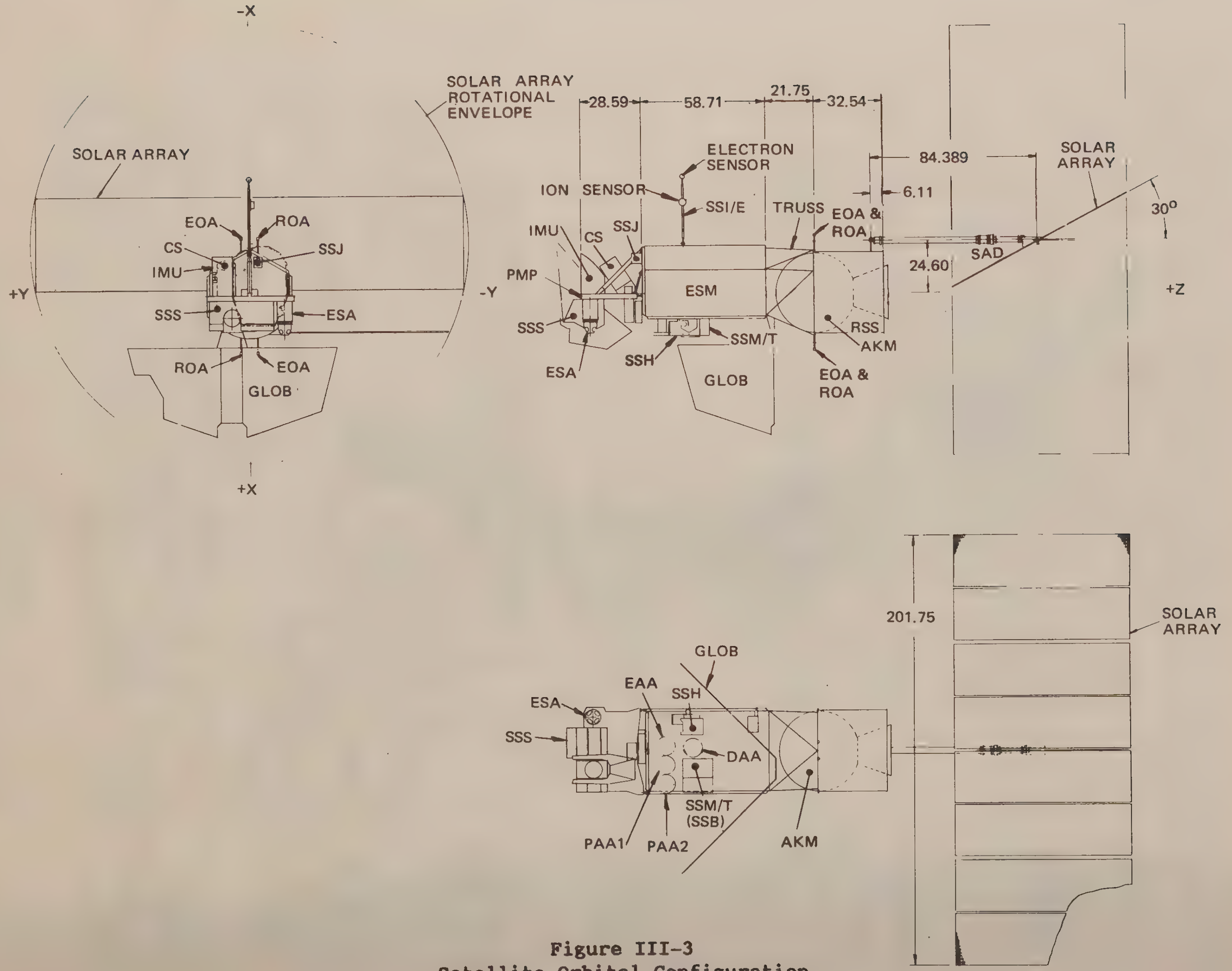

-X
SOLAR ARRAY
EOA
ROA
CS
SSJ
IMU
+Y
-Y
SSS
ESA
ROA
EOA
GLOB
+X
SOLAR ARRAY ROTATIONAL ENVELOPE
28.59
58.71
21.75
32.54
ELECTRON SENSOR
84.389
SOLAR ARRAY
ION SENSOR
6.11
SSI/E
TRUSS
EOA & ROA
30°
IMU
CS
SSJ
SAD
PMP
24.60
ESM
+Z
SSS
RSS
AKM
SSM/T
SSH
ESA
GLOB
EOA & ROA
201.75
SOLAR ARRAY
GLOB
EAA
SSH
ESA
SSS
DAA
SSM/T (SSB)
PAA1
PAA2
AKM

Figure III-3
Satellite Orbital Configuration

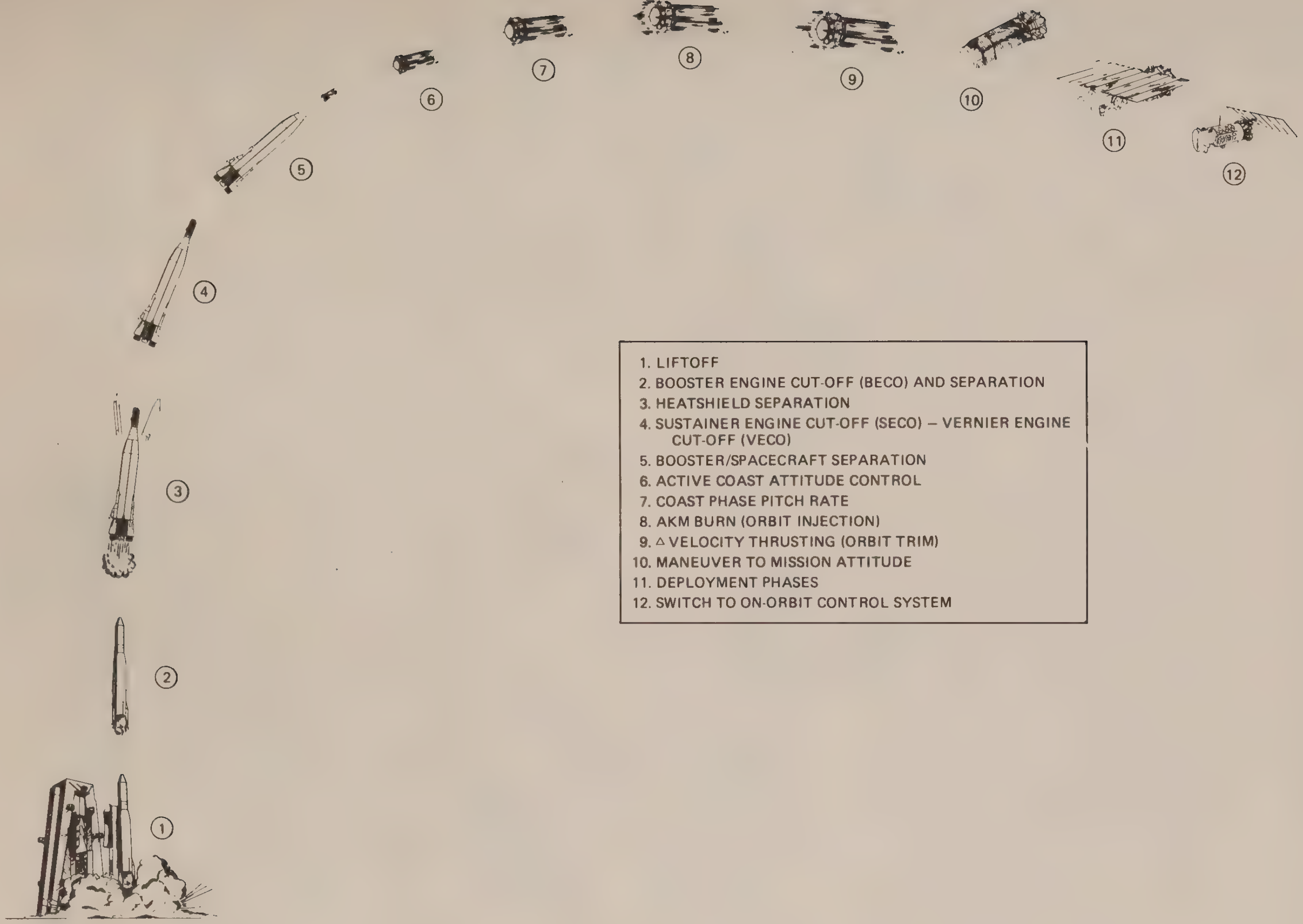

1. LIFTOFF
2. BOOSTER ENGINE CUT-OFF (BECO) AND SEPARATION
3. HEATSHIELD SEPARATION
4. SUSTAINER ENGINE CUT-OFF (SECO) – VERNIER ENGINE CUT-OFF (VECO)
5. BOOSTER/SPACECRAFT SEPARATION
6. ACTIVE COAST ATTITUDE CONTROL
7. COAST PHASE PITCH RATE
8. AKM BURN (ORBIT INJECTION)
9. △ VELOCITY THRUSTING (ORBIT TRIM)
10. MANEUVER TO MISSION ATTITUDE
11. DEPLOYMENT PHASES
12. SWITCH TO ON-ORBIT CONTROL SYSTEM
①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
⑪
⑫

Figure III-4
Launch and Ascent Sequence

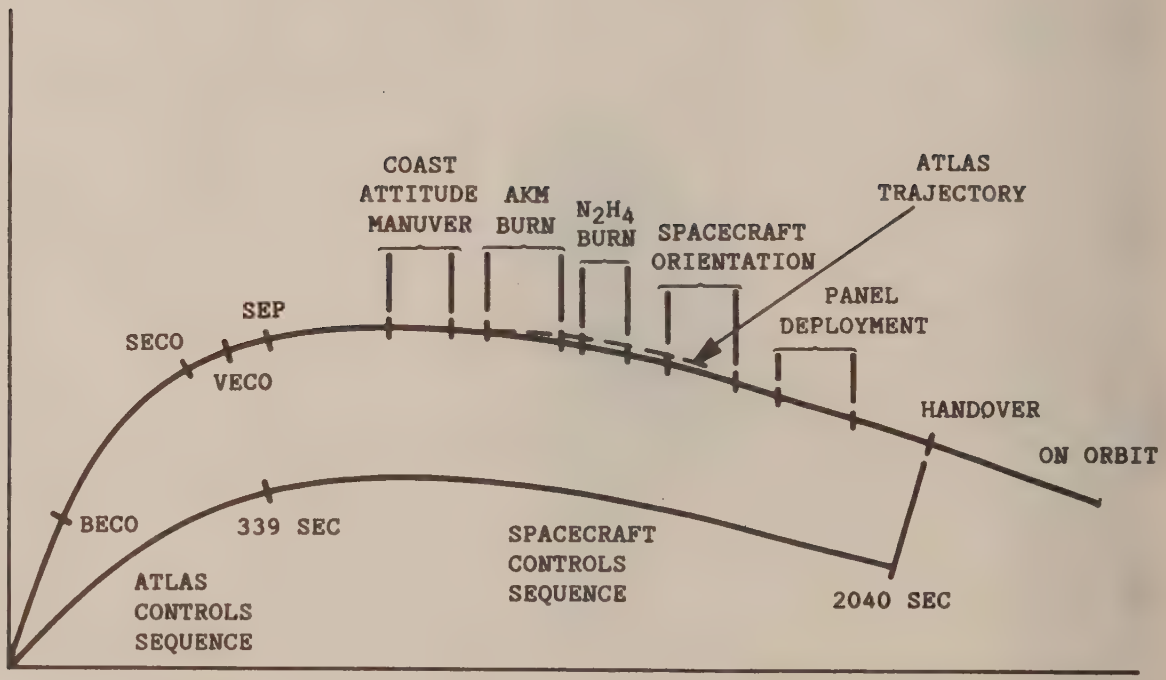

COAST
ATTITUDE
MANUVER
AKM
BURN
N_2H_4
BURN
SPACECRAFT
ORIENTATION
ATLAS
TRAJECTORY
PANEL
DEPLOYMENT
SEP
SECO
VECO
HANDOVER
ON ORBIT
BECO
339 SEC
SPACECRAFT
CONTROLS
SEQUENCE
ATLAS
CONTROLS
SEQUENCE
2040 SEC

Figure III-5
Ascent Trajectory

After hand-over to orbital operations, the SSI/E boom deployment is initiated, during which the SSI/E boom swings into alignment with the X axis.

When all deployments have occurred to give the orbital configuration shown in figure III-3, the satellite achieves the proper attitude by successively acquiring and locking onto the Earth in the pitch and roll axes (search mode) while nulling the rates about the yaw axis, and then acquiring the proper attitude on the yaw axis (gyro compassing mode). After stable operation is confirmed, the attitude control subsystem can be commanded into the nominal mode, which utilizes data from the ESA, Sun Sensor Assembly, and gyros to provide attitude control to better than 0.20 degrees. Switching to the precision attitude control mode occurs only by command and only after an accurate ephemeris and star catalog are loaded into the satellite memory. The precision mode uses gyro data with star sensor updates to provide the precision attitude control capability of 0.01 degrees.

The orbital spacecraft weight is approximately 840 kg, including the 272 kg sensor payload and the spent 48 kg AKM. After injection into orbit, the solar array is deployed, and the long axis (Z) of the satellite is oriented normal to the orbit plane. The attitude control system maintains the X axis pointed at the Earth continuously during each orbit, while a single-axis drive keeps the solar array oriented toward the sun.

In the designator ISS, the word "integrated" is used to emphasize the dual utilization of numerous components and subsystems for both the ascent and orbital phases of the mission. Equipment so employed include a telemetry processing unit and transmitter, power supply batteries and voltage regulators, computers and interface electronics, and a mutually orthogonal set of three inertial gyroscopes. This approach minimizes the ISS lift-off weight, and significantly reduces the complexity and cost of the overall system.

The ISS is subdivided into the following eight subsystems:

Ascent Phase Equipment (APE). This equipment protects the satellite during lift-off, guides it into orbit after booster separation, and positions the spacecraft in near-orbital attitude. It also generates steering correction signals to the booster and provides for launch-phase destruct capability.

- Booster Adapter and Heatshield Assembly (HA). Protecting the satellite during initial ascent, the heat shield consists of a cylindrical aluminium shell, 213 cm in diameter, and 755 cm-high aluminum ring frames. The HA mates to the bottom of the cone-shaped adaptor through the use of "Vee" bands or marmon clamps.

- Apogee Kick Motor (AKM) and Structure. The AKM, which remains with the orbiting spacecraft, is a TE-M-364-15 solid propellant motor capable of generating a total impulse of 189,772 kg-seconds. This motor (housed in a cylindrical structure 97 cm in diameter and 83 cm high) weighs a total of 711 kg (of which 48 kg is the spent third-stage motor). The AKM structure also supports the Reaction Control Equipment, the battery and its charge assembly, the solar array drive electronics, and the array boom and drive motor.

- Reaction Control Equipment (RCE). A pressurized nitrogen and hydrazine system, located on the periphery of the third-state structure, provides three-axis steering following booster separation. The residual GN2 is used as a backup for autonomous Reaction Wheel unloading.

The satellite structure consists of three elements (fig. III-6): the Precision Mounting Platform (PMP), used to hold the instruments requiring precise physical optical coalignment; the ESM; and the Reaction Control Subsystem Support Structure (RSS). The ESM is connected to the RSS with a titanium truss.

- Precision Mounting Platform (PMP). The primary sensor and other components requiring high-accuracy alignment are mounted to the PMP. It consists of an aluminum "egg crate" structure measuring 102 by 71 by 7 cm, and weighing 11 kg. Designed to support 91 kg, the platform is attached to the ESM by two ball joint mountings at each end. The platform is thermally insulated from its components and from the ESM by Polycarbofil washers and bushings. The total weight of the PMP and its attachments is 16 kg.

- Equipment Support Module (ESM). The ESM is fabricated with 3 cm of thick aluminum honeycomb. Mounted to the ESM are the S-band turnstile directional antennas, some of the mission sensors, and various electronic components. The sensors and antennas are attached to an Earth-facing panel; the electronic components are located on the inner surfaces.

- The Reaction Control Subsystem Support Structure (RSS). The RSS is an aluminum monocoque cylinder to which the batteries and reaction control equipments are attached externally, and the AKM is mounted internally.

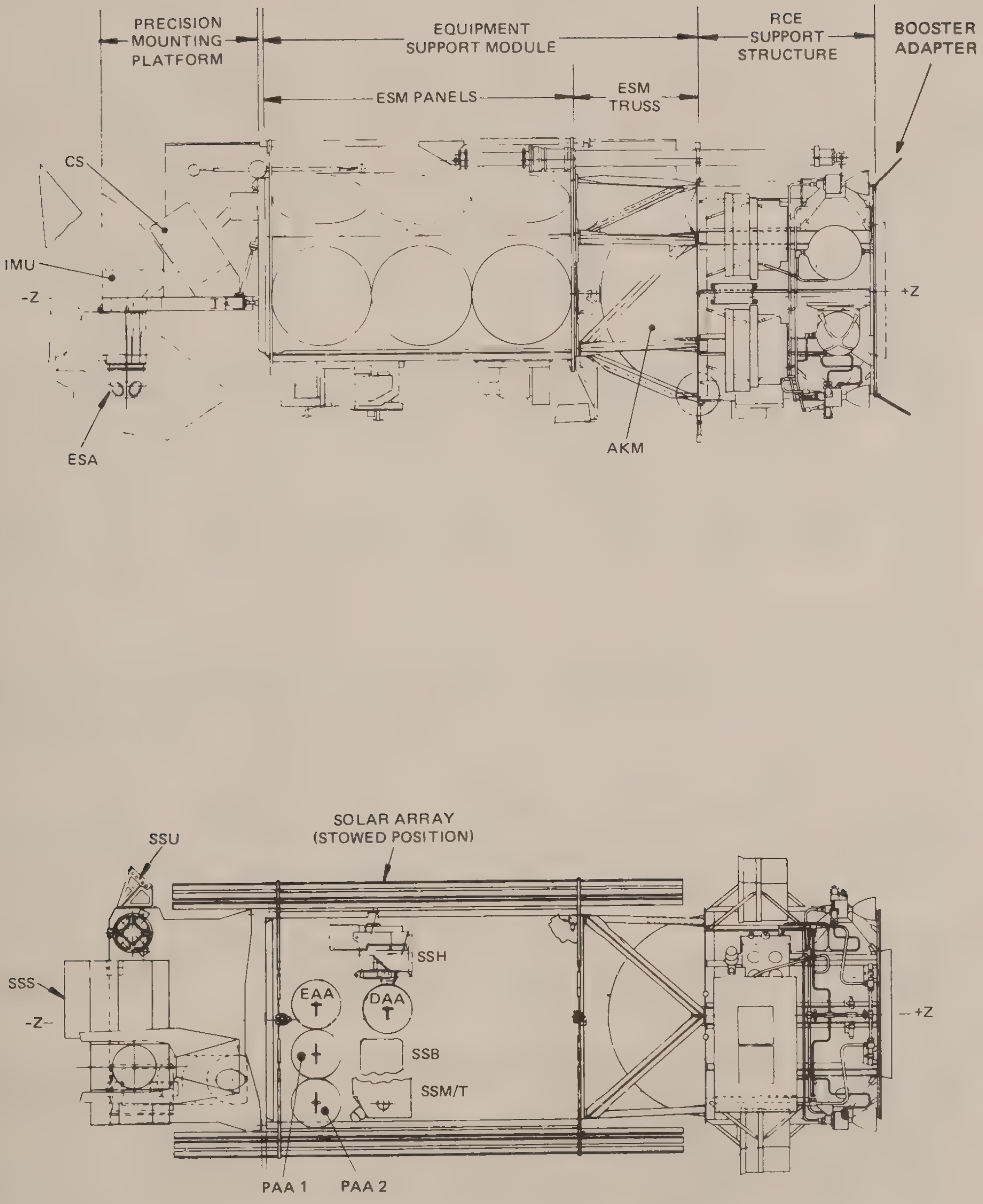

PRECISION MOUNTING PLATFORM
EQUIPMENT SUPPORT MODULE
RCE SUPPORT STRUCTURE
BOOSTER ADAPTER
ESM PANELS
ESM TRUSS
CS
IMU
-Z
+Z
ESA
AKM
SOLAR ARRAY (STOWED POSITION)
SSU
SSH
SSS
-Z
EAA
DAA
SSB
SSM/T
+Z
PAA 1
PAA 2

Figure III-6
Satellite Structure Subsystem

Thermal Control. Both active and passive thermal controls are employed to maintain correct temperature of all components and electronics, some to within ±2 °C of a nominal desired temperature.

Power. The power subsystem direct energy transfer (DET) configuration provides a direct connection between the power source and the load, eliminating the conventional series regulator with its inherent losses. The system provides high-efficiency regulated +28 volt direct current power under a wide variety of load conditions. During sunlight, power is generated by a sun-tracking solar array and transferred to the spacecraft via slip rings. At night, power is supplied from rechargeable nickel cadmium batteries.

- Solar Array (SA). A deployable, coplanar, sun-tracking solar array, canted at 28 degrees to the spacecraft pitch axis, provides power when the spacecraft is in sunlight. The eight-panel honeycomb array is covered with 12,500 2 by 4 cm silicon solar cells. A shunt across the lower portion of each circuit dissipates unused power as heat. The array delivers at least 325 W (worst case, end of life) and as much as 1,250 W (best case, beginning of life).

- Solar Array Drive/Array Drive Electronics (SAD/ADE). The solar array is rotated, in either direction, to track the sun, by a brushless direct current motor whose position is sensed to within 24.59 mrad by Hall-effect elements. The Command and Control subsystem selects direction and one of four speeds--normal (1.030 mrad/s), slow (1.013 mrad/s), fast (1.047 mrad/s), or slew (5.236 mrad/s)--to track the sun. Power and signals are transferred by 31 gold-on-gold VacKote lubricated slip rings.

- Battery (B). Two 17-cell rechargeable nickel-cadmium batteries rated at 26.5 ampere-hours provide power at night and during peak daylight loads.

- Power Supply Electronics/Battery Charge Assembly (PSE/BCA). This functional unit automatically selects the power subsystem mode to regulate the array and battery output to the spacecraft. Providing a bus voltage of +28 volts at load currents up to 20 amperes, the unit consumes less than 618 W under worst case conditions. It senses battery state-of-charge and controls charge current at one of four rates from C/2 (15A) to C/30 (0.8A). It is fully redundant, with switchover occurring either automatically or by ground command.

Communications and Telemetry. The communications subsystem includes five S-band spacecraft-to-ground links--three for data, two for telemetry, and an S-band ground-to-spacecraft command link. Separate antennas are provided for each link. The telemetry links can also be used as backup for the data links if necessary.

- Command Link. The SGLS-compatible command link operates at 1791.748 MHz. It includes an omnidirectional quadrifilar pair antenna, a filter network, and a fully redundant receiver-demodulator unit.

- Telemetry Processing. During ascent, telemetry data are processed at 60 kbps. In orbit, telemetry speed is selectable at 2 kbps (slow PCM) or 10 kbps (fast PCM). In the boost mode, 384 analog points, 256 discretes, 120 CPU telemetry words, and three vibration sensors can be accommodated. Other combinations are used in the orbit mode.

The DMSP satellite has two separate attitude determination systems. This is one of the major differences between the DMSP and POES spacecraft buses. The two independent systems are designated as the precision and basic. The precision is based on the use of a star sensor as described in the following section. The two systems operate continually with the basic considered as the umpire (i.e., if the pointing as monitored by the basic is off by more than 0.4, then it switches autonomously). The POES utilizes only the basic system.

Precision Attitude Determination and Control. An extremely accurate (better than 0.01 degrees) three-axis attitude determination and control subsystem permits precise pointing of the sensor payload located on the PMP. Three onboard orthogonal gyroscopes measure short-term changes in attitude. A star sensor provides the data necessary to compensate for gyro drift. An onboard processor stores ephemeris data and computes the satellite attitude. To enhance pointing accuracy, extensive star catalogs and ephemeris tables are periodically transmitted to the spacecraft from the ground. A backup gyroscope is available in the event of failure of any of the other three. Attitude control is provided by three reaction wheels in an active closed-loop configuration (with a fourth for backup), and by magnetic coils for unloading excess momentum.

- Inertial Measurements Unit (IMU). An IMU located on the PMP measures the satellite angular rates of the roll, pitch, and yaw axes, utilizing four miniature single-degree-of-freedom gyroscopes. The IMU converts attitude rates and star transit times to digital signals. All circuitry is redundant, and may be switched automatically or from the ground.

- Celestial Sensor Assembly (CSA). The six-slit star transit sensor utilizes a six-element silicon detector to detect stars of a magnitude of +4.0 or brighter. With a fixed 10.7 degree field-of-view, it provides a pulse output representing star transit time to enable corrections for satellite position and gyroscope drift. For correct identification, stars observed by the CSA are compared to a selectable onboard catalog of 80 stars.

- Reaction Wheel Assembly (RWA). Three orthogonally mounted, cylindrically shaped miniature ball bearing reaction wheels, and a fourth, skewed for backup, provide attitude control in the roll, yaw, and pitch axes. Each wheel is driven by a 16-pole brushless direct current motor. The beryllium wheel turns on a stainless steel gyroscope-quality bearing set, which is hermetically sealed in a helium-filled magnesium alloy housing.

Basic Attitude Determination and Control. In the event of failure of the IMU or CSA, lower-accuracy (0.12 degrees) three-axis attitude determination and control is available using the Earth Horizon and Sun Position sensors. When the precision system is working normally, the backup sensors operate in the monitoring mode, and represent an additional data source.

- Earth Sensor Assembly (ESA). The infrared Earth horizon CO_2 sensor is designed to operate at altitudes between 741 and 926 km. It views the horizon in four quadrants, each using a detector set. Each set consists of three Earth-viewing detectors, a space-viewing detector, and a common objective lens.

- Sun Sensor Unit (SSU). The sun sensor is designed to provide once-per-orbit yaw axis attitude position measurements. This augments the ESA data, which can only provide roll and pitch axis attitude position error data.

- Magnetic Torquing Coils. External disturbance torques and the rotating solar array cause an accumulation of angular momentum in the reaction wheels. The Magnetic Torquing Coils enable the spacecraft to "dump" excess angular momentum that accumulates in the Reaction Wheel Assemblies.

Command and Control. The all-digital Command and Control subsystem provides guidance signals during ascent, and controls the spacecraft attitude and operating modes while in orbit. On-orbit control may be handled by commands and data from the ground or from other onboard subsystems. The system includes redundant central processing units (one containing the ascent load program during ascent), a high-stability redundant crystal oscillator, and interface circuitry.

- Central Processing Unit (CPU). The spacecraft carries two CPUs, with switchover either automatically or by ground command for full redundancy. Each is a miniature, general purpose data processor that uses fractional fixed point, 2's complement arithmetic. Containing bulk CMOS, LSI, and CMOS SOS devices, the processors provide real-time "hands-off" attitude and operational control. Each unit has 32K 16-bit words of read/write memory that can be programmed by ground command. Microprogram control provides a set of 52 instructions in a CMOS read-only memory. Each processor operates at a speed of 2.34 microseconds per elementary operation. The processors employ welded-wire circuit boards, each containing approximately 100 chips. Each CPU measures 28 x 38 cm, weighs 6 kg, and uses 5 W of power.

- Controls Interface Unit (CIU). The CIU is a "switching center" between the CPUs and the spacecraft. It coordinates the two CPUs, receives and verifies command messages, generates all spacecraft clock and timing signals, and transfers data and control signals between the CPUs and other spacecraft units. The unit also uses CMOS-integrated circuits, and has a power converter to meet the CMOS requirements. The unit measures 29 x 19 x 21 cm, weighs 5.7 kg, and consumes 3.3 W of power.

- Redundant Crystal Oscillator (RXO). A pair of RXOs serve as high-stability frequency sources that provide timing for the spacecraft. Each oscillator is housed in its own temperature-controlled Dewar flask oven. In case of malfunction, switchover from one oscillator to the other is automatic. The oscillators are stable to +1 part in 10^8 short term, or +1 part in 10^6 long term. Each oscillator measures 12 x 15 x 5 cm, weighs 0.7 kg, and uses 2.3 W of power.

- Signal Conditioning Unit (SCU). The SCU interfaces the CIU and other units that require nonstandard circuits, such as torquing coils, separation ordnance, destruct, and solar array deployment mechanisms. The unit measures 22 x 20 x 16 cm and weighs 3.2 kg. It uses 0.2 W during ascent and 0.05 W in orbit.

b. Control Software. The heart of the spacecraft, and the element that makes it unique, is the use of software to perform all of the satellite control. This includes the ascent guidance and control, the orbital ADACS, and Command and Control.

The major software package is called the Flight Load Package (FLP) and contains the Ascent Load Package (ALP) and the Orbit Load Package. These are used by the CPUs to provide full in-orbit operational redundancy. The package is modularly designed for flexibility and ease of use.

- The ALP handles all steering calculations and events sequencing during ascent and orbit injection, initial attitude positioning preceding handoff to orbital controls, and the handoff to orbital controls.

- The Flight Load Package (FLP) includes all software for complete closed-loop control of the spacecraft, together with real-time override by ground command. It has been designed to be reprogrammed by ground command, if required.

  The package has a 16-level priority interrupt structure for asynchronous and periodic operations. It contains 17 major modules:

  - DFLSR, which filters signals from the IMU gyros

  - PRADS, which integrates the filtered gyro signals to provide a high-accuracy, short-term attitude reference, and includes a Kalman filter to update the gyro-derived reference using star transits sensed by the CSA

  - BADCS, which provides a backup (and monitor) lower accuracy attitude reference utilizing the ESA (plus gyro and SSU data for yaw angle)

  - ATCLS, which provides attitude control utilizing the PAS and BAS calculations

  - EPHEX, which interpolates the ephemeris from the stored table loaded via the command link

  - SUNPS, which derives sun angle and related parameters

  - MAMUS, which controls RWA momentum unloading via the magnetic torquing coils

  - SADCS, which controls the angular position of the solar array via the SAD

  - RLTPR, which reads commands from the ground stations

  - TMEVS, which reads commands from the stored-command table in the CPU

- CMDPR, which executes the commands from RTP and TIMEVS

- CYCLX, which controls overall spacecraft operation in response to system timing inputs

- MCEXS, which sets up the desired attitude determination and control mode

- DUMTEL, which controls "dumping" of CPU memory data via the telemetry link

- POPSR, a bootstrap loader in the read-only memory

- REDMN, a module for managing the satellite redundancy and making autonomous switching

- PMS, allows the satellite to manage its own power and maintain a positive energy balance

In normal spacecraft operation, attitude can be determined and controlled by the PAS and related modules in the one CPU, while being monitored by BAS and related modules in the other CPU. If attitude errors become excessive, the monitor CPU automatically assumes control. If one CPU becomes unavailable, the second CPU can perform both primary and monitor functions.

Either CPU can command other spacecraft components (via the CIU). The software also includes self-checks to verify proper cycling. If improper operation is detected, control is switched to the other CPU. However, the CPUs do not directly exchange data.

c. Orbital Hardware Reconfiguration. The use of onboard programmable computers to perform the autonomous spacecraft control functions has provided an additional unanticipated benefit: it has been possible to physically reconfigure the spacecraft to overcome component degradation or failures. Those spacecraft control functions that have the computer in the loop are:

- Precision attitude determination

- Basic attitude determination

- Attitude control

- Sun position/ephemeris determination

- Solar array drive control

- Mode control selected attitude determination and control modes

- Real-time command processing

- Momentum unloading

- Stored command table processing

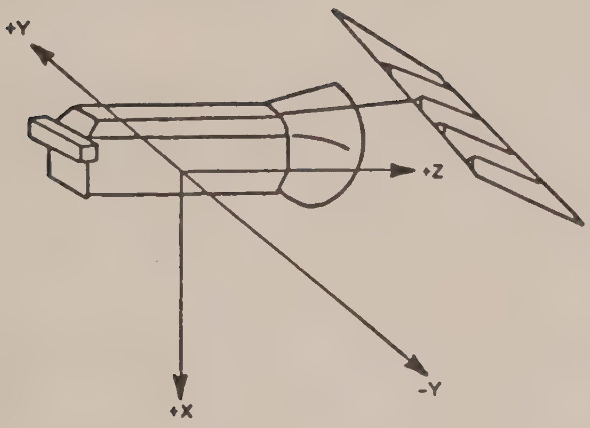
- Power management/redundancy management

Virtually all of these control loops have been modified by changing the onboard computer software to compensate for some hardware anomaly, or to enhance system performance.

2. POES

The POES satellite in its mission-orbit configuration is shown in figure III-7. It is a three-axis stabilized satellite oriented as shown in the inset, with the optical instruments maintained continuously Earth pointing. The solar array, shown fully deployed, counter rotates about the pitch axis at one revolution per orbit to provide single-axis sun orientation over the specified mission-orbit sun-angle range of 0 to 68 degrees (soon to be 0 to 80 degrees). POES, like its predecessors in the TIROS-N series, is an integrated satellite that combines the functions of operational satellite and launch vehicle upper staging. For the Atlas launch, it furnishes the impulse capability for orbital injection and velocity trim (Atlas achieves a ballistic trajectory). The necessary propulsion, control, guidance equipment, and associated software form part of the satellite, and are later used in part for mission-orbit attitude control. The satellite/ground system interface summary is shown in table III-3.

The satellite is built up from four major assemblies: the IMP, the ESM, the RSS, and the SA assembly. The IMP is the primary instrument mounting surface, and houses those instruments that have the more stringent pointing requirements, or that need an uninterrupted view of space for detector-cooling purposes. These instruments are the AVHRR, the SSU, and the HIRS/2. The IMP also supports the primary attitude-sensing equipment: an Earth horizon sensor, an inertial measuring unit, and a sun sensor. The platform is of an open-web type of construction, machined from solid aluminum with a highly reflective finish. Designed to minimize thermal gradients and distortion, it provides a stable surface on which the instruments and attitude sensors can be mutually aligned. The platform itself is supported from the ESM by four pin-jointed struts, preventing deformation due to external loading. Overall, the approach



AXIS	MISSION
+X	EARTH FACING
-X	
+Y	
-Y	VELOCITY VECTOR
+Z	ORBIT NORMAL
-Z	

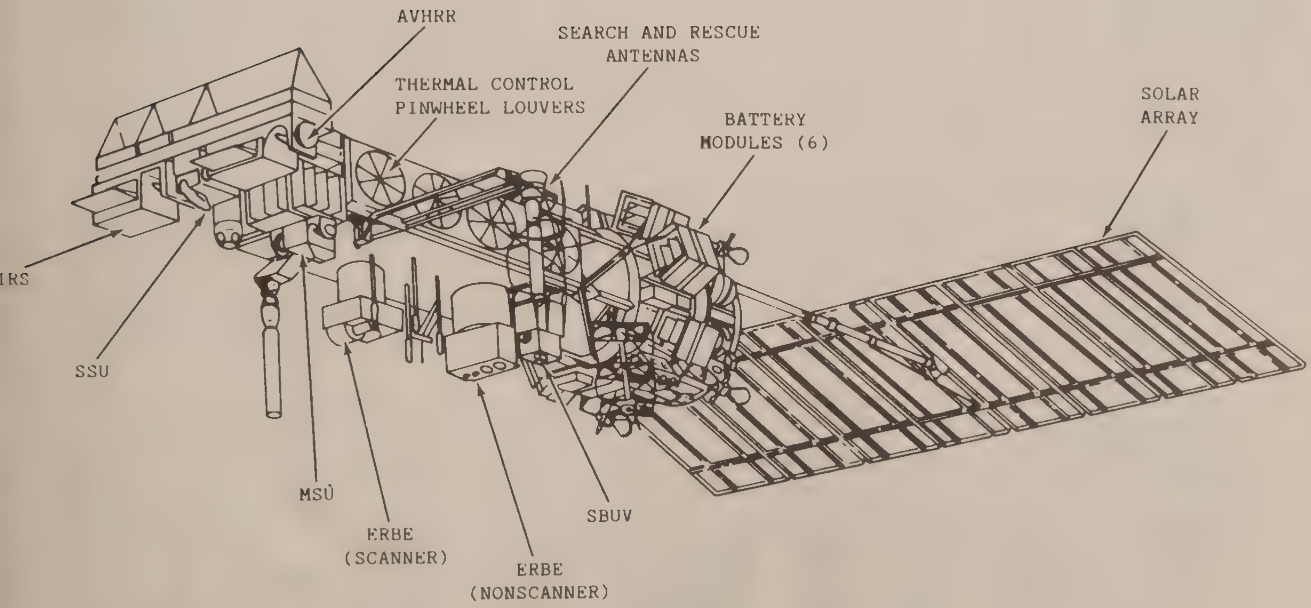

AVHRR
SEARCH AND RESCUE ANTENNAS
THERMAL CONTROL PINWHEEL LOUVERS
BATTERY MODULES (6)
SOLAR ARRAY
IRS
SSU
MSU
ERBE (SCANNER)
ERBE (NONSCANNER)
SBUV

Figure III-7
POES Mission-Orbit Configuration

Table III-3
Satellite/Ground System Interface Summary

Ground System RF Signal/ Data Rate	Gilmore Creek CDA	Wallops Island CDA	European TIP Dump Station	Standard HRPT Station	Standard Direct Readout TIP	Standard APT Station	Standard DCS Station	SAR Local Stations	Emergency Transmitters	WTR/ NAGE *	Area Aircraft **
S-Band Stored LAC/GAC Data 1.33-Mbps Split-Phase or NRZ 2.66 Mbps	Rx	Rx									
S-Band Stored TIP Data Split-Phase 0.33 Mbps	Rx	Rx	Rx							Rx	
S-Band Stored Boost Mode Data Split-Phase 0.33 Mbps	Rx	Rx								Rx	
S-Band Real-Time HRPT Data Split-Phase 0.66 Mbps	Rx	Rx		Rx							
S-Band Real-Time TIP Data Split-Phase 8.3 and 16.6 kbps	Rx	Rx								Rx	Rx
VHF Beacon Real-Time TIP Data Split-Phase 8.3 kbps	Rx	Rx	Rx***		Rx						
VHF Real-Time AM-Subcarrier 2.4 kHz		Rx				Rx					
VHF Command 1 kbps	Tx	Tx	Tx****							Tx	
UHF DCS 400 bps	Calibration Tx	Calibration Tx					Tx				
SAR Uplink 400 bps and Analog									Tx		
SAR Downlink 2400 bps and Analog								Rx			

* Prelaunch, launch, and first-pass support only
** Launch support only
*** Early orbits and emergency only
**** Emergency only

achieves an instrument optical axis pointing accuracy of better than 0.2 degrees relative to the local vertical.

The rear surface of the IMP is the primary thermal-control surface for the instruments. It houses an array of thermal-control louvers, protected from solar illumination in mission orbit by a sun shade.

The second major assembly, the ESM, contains the majority of the satellite electronic support equipment. It is pentagonal in section, but unsymmetric, to provide a large Earth-viewing face upon which lower pointing-accuracy instruments (the SBUV, the MSU, the SEM, and the SAR and DCS antennas) are mounted. Three sides of the ESM are hinged to allow access for integration and test. The arrangement of internal equipment is shown in figure III-8. All seven surfaces are used to achieve an acceptable layout in terms of mass balance, functional grouping, and harness design. The ESM houses most of the components comprising the data handling, guidance and control, communications, Command and Control, and power subsystems, as well as elements of the instrument complement that do not require external viewing. One segment of the mounting area, at the lower end of the module, is primarily dedicated to Search and Rescue equipment.

The ESM is constructed of honeycomb panels mounted to a light aluminum frame. It is connected to the RSS via a titanium truss, which also serves as a high-impedance thermal path to minimize thermal coupling between the RSS and the ESM. Thermal control of the ESM itself is provided by the pinwheel louver assemblies depicted in figure III-7.

The principal function of the RSS, as its name implies, is to accommodate the satellite propulsion equipment. It is a 116.84 cm diameter circular cylinder of skin stringer construction, which, at its lower end, provides the interface with the Atlas launch vehicle via a V-band separation system and conical adapter.

The POES propulsion system is a hybrid solid/liquid/cold-gas system. The solid rocket motor, a Thiokol TE-M-364-15, which is mounted within the RSS, provides the bulk of the WV capability for orbit (apogee) injection. This motor will be referred to as the Apogee Kick Motor (AKM) in the following sections. The hydrazine reaction control system, consisting of four 444.8 N (100-lbf) thrusters, and two spherical storage tanks, is mounted on the periphery of the RSS near the Atlas separation plane. The hydrazine feed system is a regulated constant-pressure design that uses gaseous nitrogen from the cold-gas system for pressurization. The hydrazine system provides WV capability for spacecraft separation from the

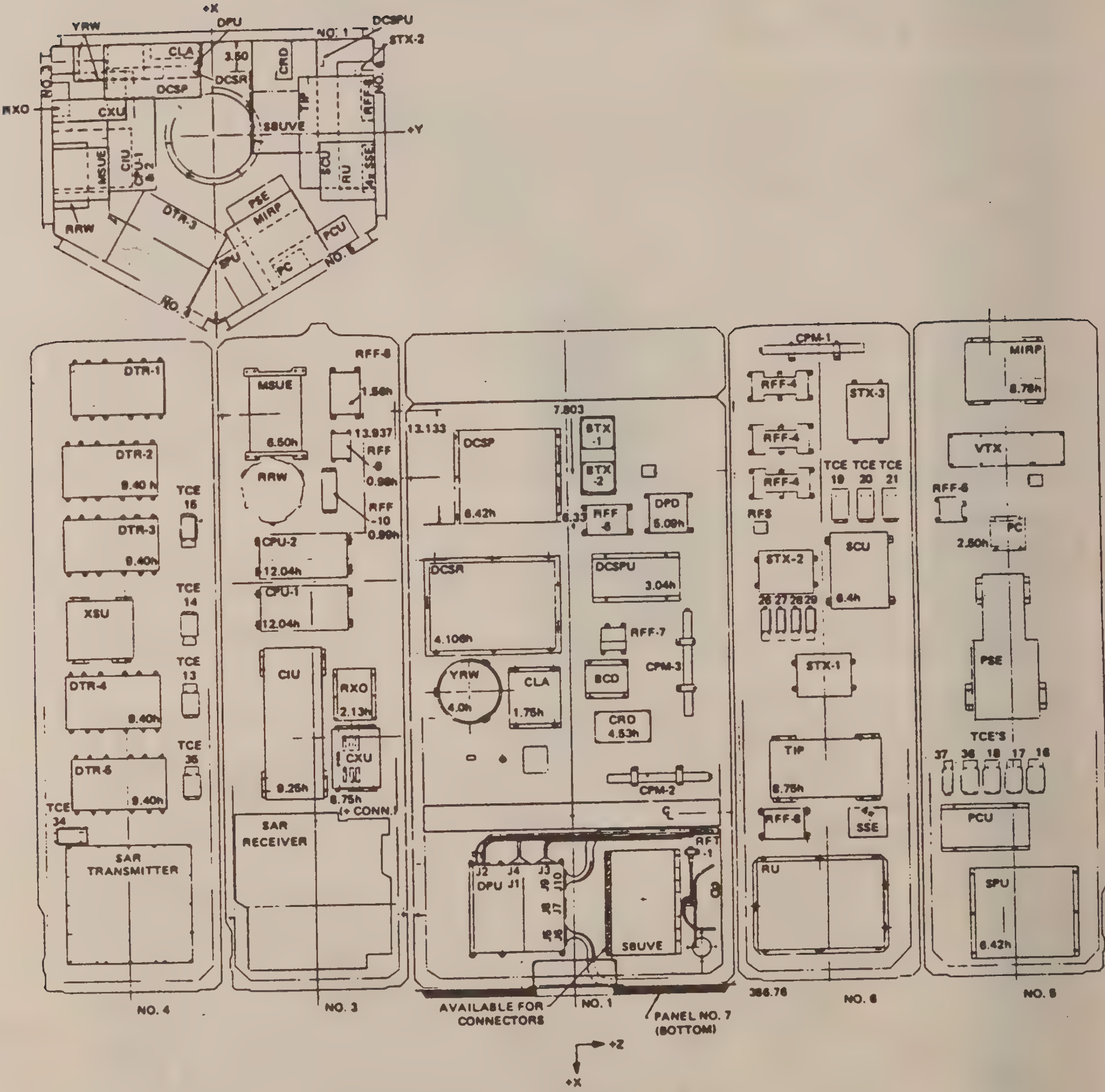

+X
YRW
DPU
NO. 1
DCSPU
STX-2
NO. 3
CLA
3.50
CRD
DCSR
DCSP
NO. 6
RFF
RXO
CXU
TIP
SBUVE
+Y
MSUE
CIU
CPU-1
& 2
SCU
RU
SSE
PSE
MIRP
DTR-3
RRW
PCU
SPU
PC
NO. 5
NO. 4
DTR-1
DTR-2
9.40 h
DTR-3
9.40h
TCE 15
TCE 14
XSU
TCE 13
DTR-4
9.40h
TCE 35
DTR-5
9.40h
TCE 34
SAR TRANSMITTER
NO. 4
RFF-8
MSUE
6.50h
1.56h
13.937
RFF -9
0.98h
RRW
RFF -10
0.90h
CPU-2
12.04h
CPU-1
12.04h
CIU
9.25h
RXO
2.13h
CXU
8.75h
(+ CONN.)
SAR RECEIVER
NO. 3
13.133
7.803
DCSP
6.42h
BTX -1
BTX -2
6.33
RFF -5
DPD
5.09h
DCSR
4.106h
DCSPU
3.04h
RFF-7
YRW
4.0h
CLA
1.75h
BCD
CPM-3
CRD
4.53h
CPM-2
℄
RFT -1
J2
J4
J3
DPU
J1
J10
J9
J7
J8
J5
J6
SBUVE
AVAILABLE FOR CONNECTORS
NO. 1
PANEL NO. 7 (BOTTOM)
+Z
+X
CPM-1
RFF-4
STX-3
RFF-4
RFF-4
TCE TCE TCE
19 20 21
RFS
STX-2
SCU
26 27 28 29
6.4h
STX-1
TIP
8.75h
RFF-6
SSE
RU
386.76
NO. 6
MIRP
8.78h
VTX
RFF-6
PC
2.50h
PSE
TCE'S
37 36 18 17 16
PCU
SPU
6.42h
NO. 5

Figure III-8
Satellite Internal Arrangement

Atlas booster and orbit circularization trim, as well as pitch and yaw control during the AKM burn.

The cold nitrogen gas system consists of eight 8.9 N thrusters and two spherical storage tanks that are also mounted on the periphery of the RSS. This system is used for three-axis control during ascent (except as mentioned earlier during AKM burn), Earth acquisition after hand-over, and as a backup for momentum control during the mission phase.

In addition to the propulsion equipment, the RSS supports the satellite batteries, battery charge controllers (for thermal reasons these items are outside the ESM), and certain of the antennas. It also furnishes support for the solar array assembly.

The solar array is a single-axis sun-tracking array consisting of eight hinged honeycomb panels with a total area of 11.6 m^2. During mission operations, the array rotates continuously about its support boom under the control of the satellite computer. It is canted at 36 degrees to the boom axis to optimize performance over the 0 to 68-degree sun angle range. During launch, the array is "wrapped" around the four anti-Earth sides of the ESM, held by two circumferential cables that are released and fly away at the appropriate time in the ascent sequence. Passive spring/dampers have been selected as the deployment mechanisms.

Overall dimensions of the satellite are determined by the constraints of the Atlas fairing. Predeployment dimensions are 181 cm diameter (max.) by 419 cm overall length. The length increases to 746 cm subsequent to array deployment. A summary of the general characteristics of the POES satellite is shown in figure III-9. The 551 W power capability provided is sufficient to support additional instrumentation should the mission requirements be extended at a later time.

The specified launch weight is 1712.3 kg.

Subsystem	Weight (kg)	(lb)
Structure	203.3	448.3
Thermal	43.0	94.9
ADACS (Dry)	55.7	122.9
Power	163.0	359.4
Communications	25.1	55.4
Command and Control	27.7	61.1
Data Handling	16.4	36.1
GFE Payload	265.8	585.9
Payload Margin/Growth	65.5	144.5
Harness and RF Cables	72.3	159.3

SATELLITE AND MISSION ORBIT CHARACTERISTICS

Size

- 165" high by 74" diameter (excluding solar energy)

Configuration Type

- Mulisectioned stack
  - Instrument Mounting Platform
  - Equipment Support Module
  - Reaction Control Support Structure

Weight

- On orbit: 2290 lb.
- At liftoff 3775 lb.

Power

- 551 watts, orbit average load capability

Lifetime

- Goal of greater than 2 years

Operational Sun Angle

- 0° to 68°

Nominal Altitude

- 450 nmi (833 km) or 470 nmi (870 km)

Orbit Inclination

- 98.739° for 450 nmi or 98.899° for 470 nmi

Orbit O'Clock Angle (Nominal)

- 07:30 descending node
- 02:30 descending node

WEIGHT SUMMARY

Subsystem	Configuration Weight (lb)
Structure	456.3
Thermal	91.1
ADACS (Dry)	125.2
Power	369.4
Communications	55.6
Command & Control	60.4
Data Handling	36.1
GFE	585.9
Harness	159.3
AKM Case	106.0
Balance/Ballast	100.0
Satellite Margin	18.4
Satellite Dry Weight	2267.8
Hydrazine	37.9
Gaseous Nitrogen	5.3
AKM Expendables	1464.0
Liftoff Weight	3775.0

COMMUNICATIONS LINK SUMMARY

S-Band Data Links

- 1698 MHz, 1702.5 MHz, 1707 MHz
- To CDA stations, HRPT stations, and European stations
- Split phase or NRZ data with PSK modulation
- 2.66, 1.33 and 0.33327 Mbps

S-Band Launch Telemetry Link

- 1702.5 MHz
- To NAGE at WTR and to ARIA aircraft
- Split phase data with PSK modulation
- 16.64 kbps, 8.32 kbps

VHF APT Real-Time Link

- 137.5 or 137.62 MHz
- To APT stations
- ≈2kHz baseband
- AM/FM modulation

VHF Beacon Link

- 136.77 MHz, and 137.77 MHz
- To CDA stations, TIP stations, and in early orbit and emergency to European station
- Split phase data with PSK modulation
- 8320 bps

VHF Command Link

- 148.56 MHz
- From DCA stations; also in emergency from European station and WTR
- Ternary FSK, AM
- 1 kbps

DCS Uplink

- 401 MHz
- From Platforms
- Split Phase PSK
- 400 bps

SAR Uplink

- 121.5, 243, and 406.05 MHz (FM/AM)
- 406.025 MHz (Split Phase PSK)
- From emergency transmitters

SAR Downlink

- 1544.5 MHz (PM)
- To Local Stations
- PM Modulation

Figure III-9
POES Satellite Characteristics

SUBSYSTEM CHARACTERISTICS

Attitude Determination and Control

- Zero momentum system
- Reaction wheel control with magnetic momentum unloading
- Earth stabilized
- Three-axis determination and control
- <±0.2° control accuracy
  <±0.15° attitude knowledge
  <0.035°/second ptich/year rates
  <0.015°/second roll rates

Reaction Control

- Monopropellent hydrazine system, used for:
  - Control during AKM burn
  - Orbit injection velocity trim
- Gaseous Nitrogen System, used for:
  - Hydrazine pressurization
  - Coast control
  - Control during ΔV maneuvers
  - Momentum unloading

Apogee Kick Motor

- TEM-364-15 solid motor

Themal Control

- Passive control components
  - Blankets, finishes, insulators, shades
- Active control components
  - Pinwheel and vane louvers, heaters, control electronics

Power and Distribution

- Boost-Discharge DET system
- + 28-V, 10V, and 5V regulated voltage
- Single-axis oriented solar array (125 ft^2)

- 551-W orbit avg. load capability
- Three 26.5 Ah batteries

Data Handling

- Low data rate processing
  - Flexible low rate data formatter and telemetry processor
  - Boost, orbit, dwell dump modes
  - 8320 bps (orbit)
  - 16,640 bps (boost)
  - TLM; 512 analog, 352 bilevel digital B, 16 serial digital A word channels
- High data rate processing:
  - High rate data formatter and processor
  - Performs multiplexing, formatting, resolution reduction, geometric correction functions
  - Analog APT; global date (66.54 kbps); HRPT data (665.4 kbps); local data (665.4 kbps) outputs
- Data Storage:
  - 5 GFE digital data recorders
  - Record 8.32 kbps-230.5 min.
    16.64 kbps-115 min.
    66.54 kbps-111 min.
    665.40 kbps-11.1 min.
  - Playback 1.3306 Mbps-5.6 min.
    332.7 kbps-5.8 min.
    2.6616 Mbps-2.8 min.

Command and Control

- Command link bit rate: 1 kpbs
  - Effective commanding rate: 40 words/sec.
- Message Types
  - CPU Data
  - CIU decoded commands: 24 hardware capacity, 24 implemented
  - CPU decoded commands:
    - CIU pulses and levels - 400 hardware capacity, 348 implemented
    - CXU pulses and levels - 256 hardware capacity, 180 implemented
    - Serial Mode Commands
- Stored Commands
  - table capacity: 800 commands
  - time tag: 1.0 sec. granularity 36 hour clock

POWER SUMMARY

Subsystem	DC Power (Watts)
Instruments	214.6
Attitude Control	55.3
Data Handling	14.7
Thermal	120.0
Command	29.7
Communications	62.4
Power	5.9
Power Required	502.6
EOL Spacecraft Power Available	551.0

Figure III-9 (concluded)
POES Satellite Characteristics

Subsystem	Weight (kg)	Weight (lb)
AKM Case	48.1	106.0
Balance Weights	32.7	72.0
S/C and Balance Margin	10.0	22.0
Spacecraft Dry Weight	1,028.7	2,267.8
N_2H_4	17.2	37.9
GN_2	2.4	5.3
AKM Expendables	664.1	1,464.0
Spacecraft Liftoff	1,712.3	3,775.0

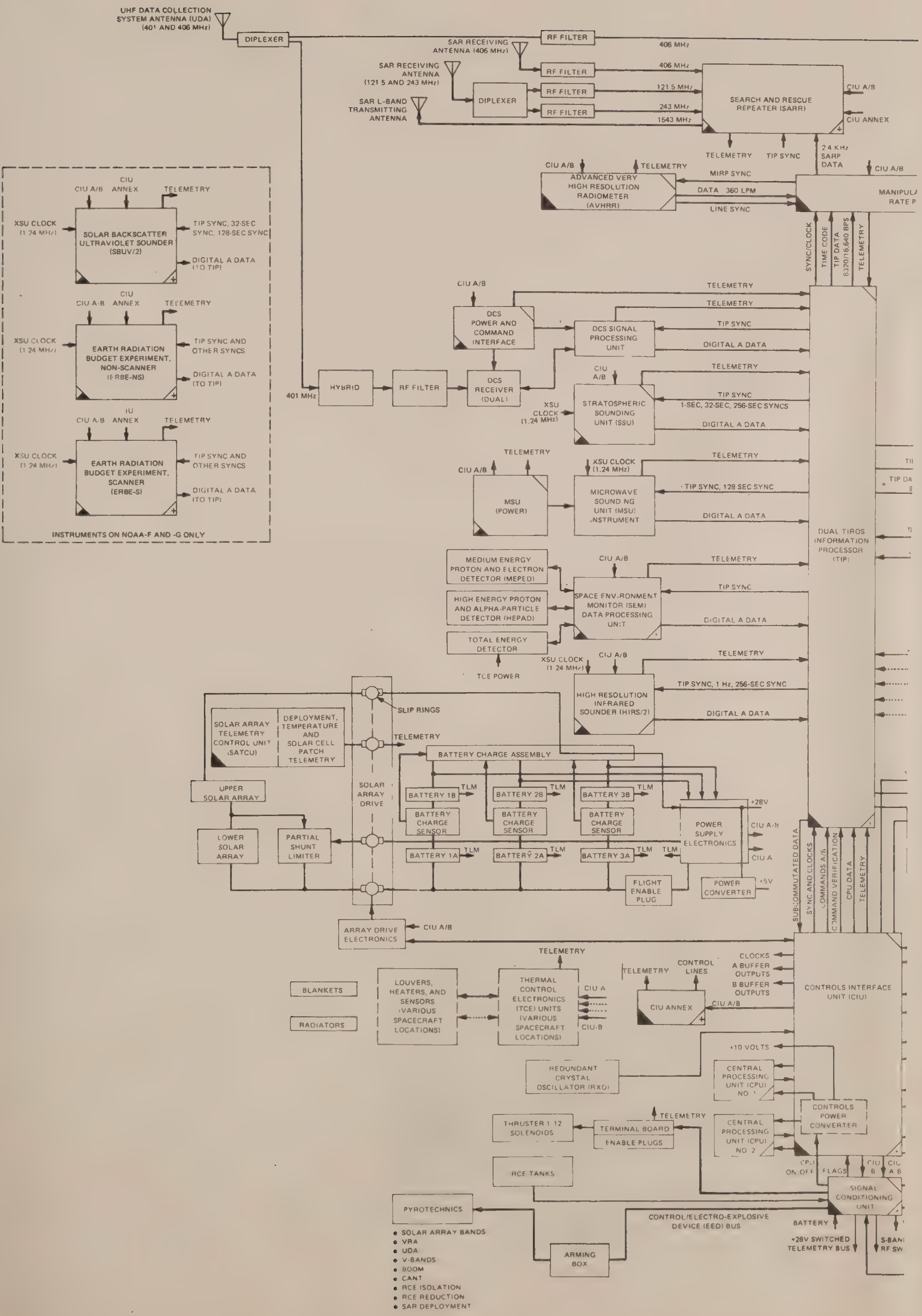
a. Satellite Subsystem Summary. A functional block diagram of the overall satellite system is shown in figure III-10. Excluding instruments, it is composed of nine subsystems:

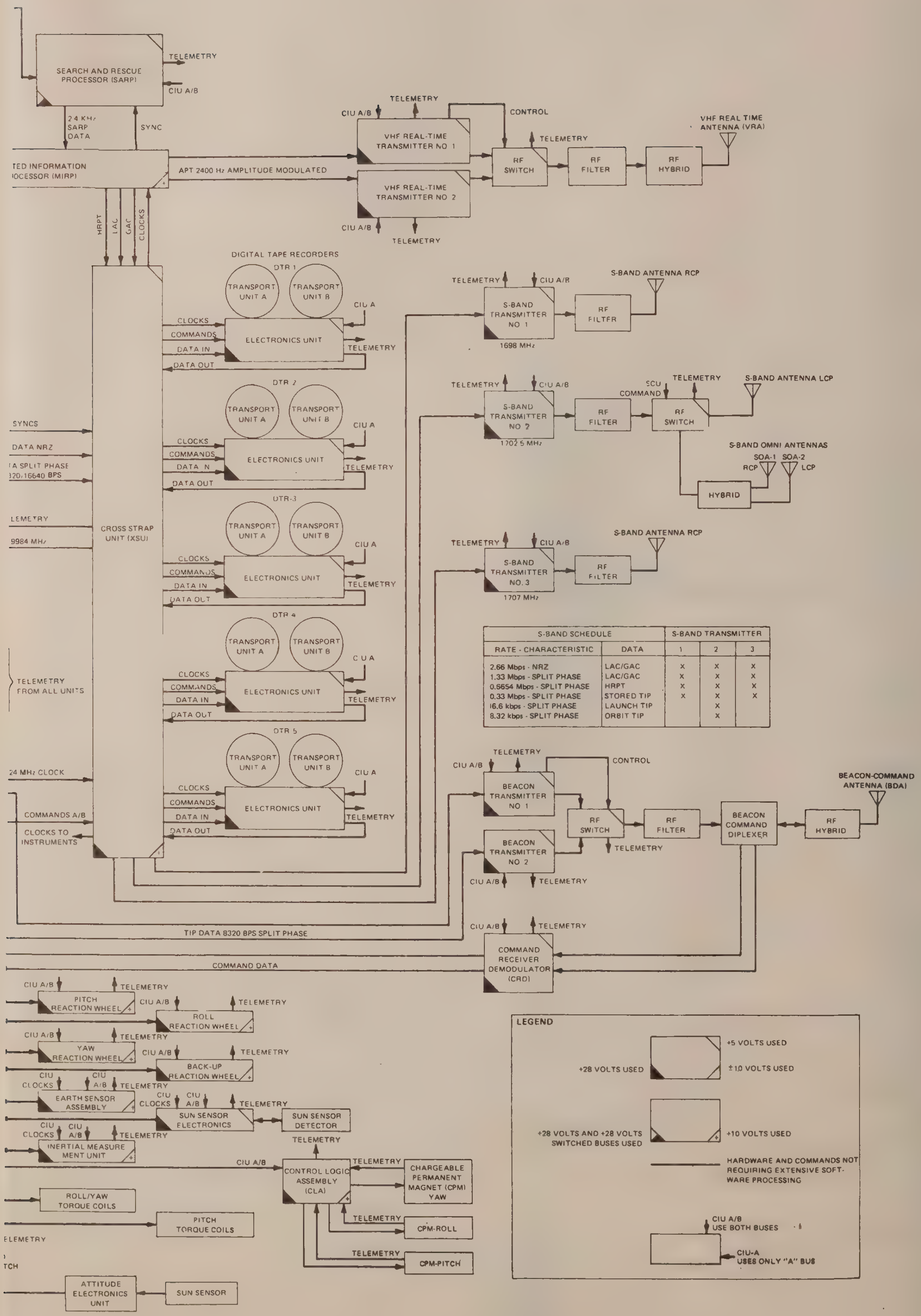
- Attitude determination and control
- Reaction control
- Data handling
- Communications
- Command and control
- Flight software
- Power
- Thermal
- Structure

For the purposes of this report, flight software is considered separately from the Command and Control hardware.

Attitude Determination and Control Subsystem (ADACS). The ADACS provides, in conjunction with the reaction control and Command and Control subsystems, the functions of on-orbit attitude control and ascent guidance. It is a zero-momentum system consisting of reaction wheels and Earth, sun, and inertial reference sensors as shown in figure III-11.

In the subsystem's attitude-control mode, the ESA together with rates derived from the IMU, a strapdown inertial reference unit containing four single-axis gyros and an orthogonal set of three accelerometers, furnish the attitude reference. Any three of the four gyros can be selected to provide an attitude reference. Control torquing is accomplished by an orthogonal set of RWAs backed up by a fourth skewed reaction wheel. The momentum accumulation in the wheels is unloaded by means of magnetic coils, which, in turn, are backed up by cold-gas thrusters. The subsystem requires ephemeris data for orbital operation, and this typically can be satisfied with a ground update once per week. In all other


UHF DATA COLLECTION SYSTEM ANTENNA (UDA) (401 AND 406 MHz)
DIPLEXER
RF FILTER
406 MHz
SAR RECEIVING ANTENNA (406 MHz)
SAR RECEIVING ANTENNA (121 5 AND 243 MHz)
SAR L-BAND TRANSMITTING ANTENNA
DIPLEXER
RF FILTER
RF FILTER
RF FILTER
406 MHz
121 5 MHz
243 MHz
1543 MHz
SEARCH AND RESCUE REPEATER (SARR)
CIU A/B
CIU ANNEX
TELEMETRY
TIP SYNC
2 4 KHz SARP DATA
CIU A/B
TELEMETRY
CIU A/B
ADVANCED VERY HIGH RESOLUTION RADIOMETER (AVHRR)
MIRP SYNC
DATA 360 LPM
LINE SYNC
MANIPULA
RATE P
SYNC/CLOCK
TIME CODE
TIP DATA 8320/16,640 BPS
TELEMETRY
CIU A/B
CIU ANNEX
TELEMETRY
XSU CLOCK (1 24 MHz)
SOLAR BACKSCATTER ULTRAVIOLET SOUNDER (SBUV/2)
TIP SYNC, 32-SEC SYNC, 128-SEC SYNC
DIGITAL A DATA (TO TIP)
CIU A/B
CIU ANNEX
TELEMETRY
XSU CLOCK (1 24 MHz)
EARTH RADIATION BUDGET EXPERIMENT, NON-SCANNER (ERBE-NS)
TIP SYNC AND OTHER SYNCS
DIGITAL A DATA (TO TIP)
CIU A/B
IU ANNEX
TELEMETRY
XSU CLOCK (1 24 MHz)
EARTH RADIATION BUDGET EXPERIMENT, SCANNER (ERBE-S)
TIP SYNC AND OTHER SYNCS
DIGITAL A DATA (TO TIP)
INSTRUMENTS ON NOAA-F AND -G ONLY
CIU A/B
DCS POWER AND COMMAND INTERFACE
TELEMETRY
TELEMETRY
DCS SIGNAL PROCESSING UNIT
TIP SYNC
DIGITAL A DATA
401 MHz
HYBRID
RF FILTER
DCS RECEIVER (DUAL)
CIU A/B
TELEMETRY
XSU CLOCK (1.24 MHz)
STRATOSPHERIC SOUNDING UNIT (SSU)
TIP SYNC
1-SEC, 32-SEC, 256-SEC SYNCS
DIGITAL A DATA
TELEMETRY
CIU A/B
XSU CLOCK (1.24 MHz)
MSU (POWER)
MICROWAVE SOUNDING UNIT (MSU) INSTRUMENT
TELEMETRY
TIP SYNC, 128 SEC SYNC
DIGITAL A DATA
DUAL TIROS INFORMATION PROCESSOR (TIP)
TI
TIP DA
MEDIUM ENERGY PROTON AND ELECTRON DETECTOR (MEPED)
HIGH ENERGY PROTON AND ALPHA-PARTICLE DETECTOR (HEPAD)
TOTAL ENERGY DETECTOR
TED POWER
CIU A/B
SPACE ENVIRONMENT MONITOR (SEM) DATA PROCESSING UNIT
TELEMETRY
TIP SYNC
DIGITAL A DATA
XSU CLOCK (1 24 MHz)
CIU A/B
HIGH RESOLUTION INFRARED SOUNDER (HIRS/2)
TELEMETRY
TIP SYNC, 1 Hz, 256-SEC SYNC
DIGITAL A DATA
SLIP RINGS
SOLAR ARRAY TELEMETRY CONTROL UNIT (SATCU)
DEPLOYMENT, TEMPERATURE AND SOLAR CELL PATCH TELEMETRY
TELEMETRY
BATTERY CHARGE ASSEMBLY
UPPER SOLAR ARRAY
SOLAR ARRAY DRIVE
LOWER SOLAR ARRAY
PARTIAL SHUNT LIMITER
BATTERY 1B
TLM
BATTERY CHARGE SENSOR
BATTERY 2B
TLM
BATTERY CHARGE SENSOR
BATTERY 3B
TLM
BATTERY CHARGE SENSOR
+28V
POWER SUPPLY ELECTRONICS
CIU A/B
CIU A
BATTERY 1A
TLM
BATTERY 2A
TLM
BATTERY 3A
TLM
TLM
FLIGHT ENABLE PLUG
POWER CONVERTER
+5V
SUBCOMMUTATED DATA
SYNC AND CLOCKS
COMMANDS A/B
COMMAND VERIFICATION
CPU DATA
TELEMETRY
ARRAY DRIVE ELECTRONICS
CIU A/B
TELEMETRY
BLANKETS
RADIATORS
LOUVERS, HEATERS, AND SENSORS (VARIOUS SPACECRAFT LOCATIONS)
THERMAL CONTROL ELECTRONICS (TCE) UNITS (VARIOUS SPACECRAFT LOCATIONS)
CIU A
CIU B
TELEMETRY
CONTROL LINES
CIU ANNEX
CIU A/B
CLOCKS
A BUFFER OUTPUTS
B BUFFER OUTPUTS
CONTROLS INTERFACE UNIT (CIU)
+10 VOLTS
REDUNDANT CRYSTAL OSCILLATOR (RXO)
CENTRAL PROCESSING UNIT (CPU) NO 1
CONTROLS POWER CONVERTER
TELEMETRY
THRUSTER 1 12 SOLENOIDS
TERMINAL BOARD
ENABLE PLUGS
CENTRAL PROCESSING UNIT (CPU) NO 2
CPU ON OFF
FLAGS
CIU B
CIU A B
RCE TANKS
SIGNAL CONDITIONING UNIT
PYROTECHNICS
CONTROL/ELECTRO-EXPLOSIVE DEVICE (EED) BUS
BATTERY
+28V SWITCHED TELEMETRY BUS
S-BAN
RF SW
ARMING BOX
• SOLAR ARRAY BANDS
• VRA
• UDA
• V-BANDS
• BOOM
• CANT
• RCE ISOLATION
• RCE REDUCTION
• SAR DEPLOYMENT


SEARCH AND RESCUE PROCESSOR (SARP)
TELEMETRY
CIU A/B
2.4 KHz SARP DATA
SYNC
TED INFORMATION
OCESSOR (MIRP)
APT 2400 Hz AMPLITUDE MODULATED
HRPT
LAC
GAC
CLOCKS
CIU A/B
TELEMETRY
CONTROL
VHF REAL-TIME TRANSMITTER NO 1
VHF REAL-TIME TRANSMITTER NO 2
RF SWITCH
RF FILTER
RF HYBRID
VHF REAL TIME ANTENNA (VRA)
DIGITAL TAPE RECORDERS
DTR 1
DTR 2
DTR-3
DTR 4
DTR 5
TRANSPORT UNIT A
TRANSPORT UNIT B
ELECTRONICS UNIT
CLOCKS
COMMANDS
DATA IN
DATA OUT
CIU A
SYNCS
DATA NRZ
A SPLIT PHASE
320/16640 BPS
LEMETRY
9984 MHz
CROSS STRAP UNIT (XSU)
TELEMETRY FROM ALL UNITS
24 MHz CLOCK
COMMANDS A/B
CLOCKS TO INSTRUMENTS
S-BAND TRANSMITTER NO 1
1698 MHz
S-BAND ANTENNA RCP
S-BAND TRANSMITTER NO 2
1702.5 MHz
SCU COMMAND
S-BAND ANTENNA LCP
S-BAND OMNI ANTENNAS
SOA-1
SOA-2
RCP
LCP
HYBRID
S-BAND TRANSMITTER NO. 3
1707 MHz
BEACON TRANSMITTER NO 1
BEACON TRANSMITTER NO 2
BEACON COMMAND DIPLEXER
BEACON-COMMAND ANTENNA (BDA)
TIP DATA 8320 BPS SPLIT PHASE
COMMAND DATA
COMMAND RECEIVER DEMODULATOR (CRD)
PITCH REACTION WHEEL
ROLL REACTION WHEEL
YAW REACTION WHEEL
BACK-UP REACTION WHEEL
EARTH SENSOR ASSEMBLY
SUN SENSOR ELECTRONICS
SUN SENSOR DETECTOR
INERTIAL MEASURE MENT UNIT
CONTROL LOGIC ASSEMBLY (CLA)
CHARGEABLE PERMANENT MAGNET (CPM) YAW
CPM-ROLL
CPM-PITCH
ROLL/YAW TORQUE COILS
PITCH TORQUE COILS
ELEMETRY
TCH
ATTITUDE ELECTRONICS UNIT
SUN SENSOR
LEGEND
+5 VOLTS USED
+28 VOLTS USED
±10 VOLTS USED
+28 VOLTS AND +28 VOLTS SWITCHED BUSES USED
+10 VOLTS USED
HARDWARE AND COMMANDS NOT REQUIRING EXTENSIVE SOFTWARE PROCESSING
CIU A/B USE BOTH BUSES
CIU-A USES ONLY "A" BUS

S-BAND SCHEDULE		S-BAND TRANSMITTER		
RATE - CHARACTERISTIC	DATA	1	2	3
2.66 Mbps - NRZ	LAC/GAC	X	X	X
1.33 Mbps - SPLIT PHASE	LAC/GAC	X	X	X
0.6654 Mbps - SPLIT PHASE	HRPT	X	X	X
0.33 Mbps - SPLIT PHASE	STORED TIP	X	X	X
16.6 kbps - SPLIT PHASE	LAUNCH TIP		X	
8.32 kbps - SPLIT PHASE	ORBIT TIP		X	

Figure III-10
Overall POES Functional Block Diagram

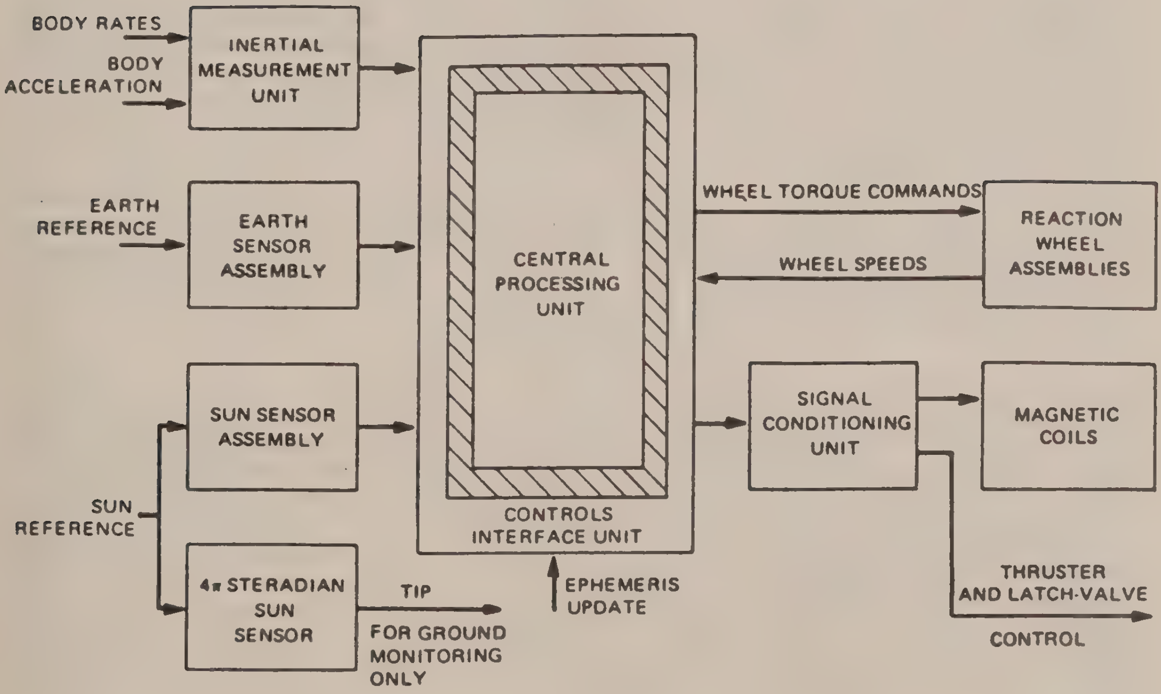

BODY RATES
BODY ACCELERATION
INERTIAL MEASUREMENT UNIT
EARTH REFERENCE
EARTH SENSOR ASSEMBLY
SUN REFERENCE
SUN SENSOR ASSEMBLY
4π STERADIAN SUN SENSOR
TIP
FOR GROUND MONITORING ONLY
CENTRAL PROCESSING UNIT
CONTROLS INTERFACE UNIT
EPHEMERIS UPDATE
WHEEL TORQUE COMMANDS
WHEEL SPEEDS
REACTION WHEEL ASSEMBLIES
SIGNAL CONDITIONING UNIT
MAGNETIC COILS
THRUSTER AND LATCH-VALVE CONTROL

Figure III-11
ADACS Simplified Block Diagram

respects, the subsystem is autonomous, including the capability for acquisition and reacquisition.

The IMU, which provides a yaw reference and pitch/roll rate information in orbital mode, is the key component in the ascent guidance phase. The same closed-loop guidance scheme previously used on TIROS-N and ATN missions is used on POES. The IMU will furnish a navigation reference from liftoff until orbit insertion and closed-loop guidance for all satellite maneuvers following separation from the launch vehicle.

Satellite attitude-control accuracy in mission orbit is ±0.2 degrees with respect to the local geodetic reference frame. Knowledge of attitude is obtainable to an accuracy of ±0.15 degrees in all axes. Attitude rates do not exceed 0.035 degrees per second in pitch and yaw, and 0.015 degrees per second in roll. In its ascent-guidance mode of operation, performance is well within that required to meet orbit-achievement accuracy specifications.

The IMU on POES has recently been upgraded. The modified IMU has improved performance characteristics, and the reliability is improved over that of the ATN unit. In addition, substantial cost savings have been realized by utilizing a common design for the POES and DMSP IMUs.

Reaction Control Equipment (RCE) Subsystem. The primary functions of the RCE Subsystem are to provide separation from the Atlas, ascent-phase attitude control (three-axis stabilized), and orbital velocity trim for the spacecraft. The RCE is activated following burnout of the Atlas booster, and continues to operate until control is transferred to the spacecraft attitude control system. At this point in the mission, the cold-gas thrusters of the RCE are utilized in the backup mode to ensure that the RWAs will not become saturated due to unanticipated disturbance torques. The hydrazine system is permanently disabled prior to hand-over to orbit mode.

The RCE is a dual system, using both pressure-regulated cold-gas nitrogen thrusters and hydrazine monopropellant thrusters. The RCE is mounted on a cylindrical support structure (the RSS) and consists of three major equipment areas:

- High-pressure nitrogen gas storage and distribution
- Regulated low-pressure nitrogen gas distribution and cold-gas nitrogen thrusters
- Liquid hydrazine storage, distribution, and thrusters

The RCE is composed of the major components and assemblies shown in figure III-12. The RCE contains 15.9 kg of usable hydrazine and 2.3 kg of usable gaseous nitrogen.

The hydrazine monopropellant thrusters are used for the maneuvers requiring large control torques, and for all velocity change (Δ V) maneuvers. The nitrogen cold-gas thrusters provide all Atlas roll control and low-control torque for Atlas pitch and yaw control. The cold-gas thrusters are also used as a backup in normal orbit mode control. The relationship between spacecraft motion and thruster actuation is shown in table III-4.

The high-pressure nitrogen is stored in two titanium tanks at an initial pressure of 310 Pa. These pressurant tanks are mounted to the spacecraft structure by means of strap assemblies. The nitrogen gas stored in these tanks provides the required total impulse for the nitrogen cold-gas thrusters, and also serves as the pressurant to expel the hydrazine from the propellant tanks. The outlets of the pressurant tanks are connected through a common high-pressure manifold. A pressure regulator at the manifold outlet reduces the gas pressure to a nominal value of 3.2 Pa. The other components shown in the schematic, which are a part of the high-pressure system, are the nitrogen fill and drain valve, a high-pressure transducer, and pressurant tank temperature sensors.

The low-pressure nitrogen output from the pressure regulator is distributed by stainless steel manifolds to the cold-gas nitrogen engines and the ullage volumes of the hydrazine propellant tanks. A mechanical relief valve incorporated into the low-pressure output side of the pressure regulator ensures that the low-pressure nitrogen manifold never exceeds a maximum pressure of 3.79 Pa. Four of the eight cold-gas thrusters provide Atlas roll control and are operated, under software control, in coupled pairs; the remaining four thrusters are operated individually to provide Atlas pitch and Atlas yaw control. These cold-gas thrusters are rated at 8.9 ± .4 N vacuum thrust. The major components of the hydrazine system are the two propellant tanks and the four hydrazine monopropellant thrusters. The two hydrazine propellant tanks incorporate positive-expulsion bladders, and provide a minimum usable propellant volume of 7,374 cm^3 each. Temperature sensors are provided on each tank. Matched trim orifices incorporated at the propellant tank outlets prevent shifts in the spacecraft center-of-gravity due to a usage misbalance. The propellant to the yaw and pitch through ster manifolds passes through high hydraulic resistance legs, incorporating combined Lee-Jet and trim orifices that reduce the flow to the rate required for a 445 N (100 lb force) thrust. After completion of the orbital velocity trim burn, pyrotechnic valves at

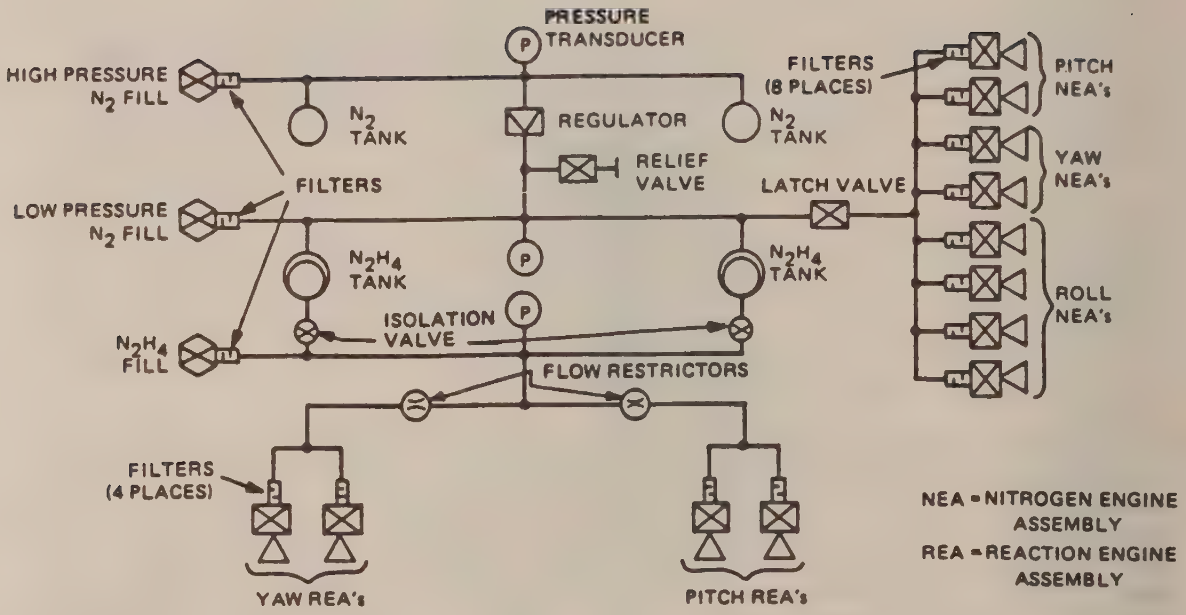

PRESSURE TRANSDUCER
HIGH PRESSURE N_2 FILL
N_2 TANK
REGULATOR
N_2 TANK
FILTERS (8 PLACES)
PITCH NEA's
RELIEF VALVE
YAW NEA's
FILTERS
LOW PRESSURE N_2 FILL
LATCH VALVE
N_2H_4 TANK
N_2H_4 TANK
ROLL NEA's
ISOLATION VALVE
N_2H_4 FILL
FLOW RESTRICTORS
FILTERS (4 PLACES)
NEA = NITROGEN ENGINE ASSEMBLY
REA = REACTION ENGINE ASSEMBLY
YAW REA's
PITCH REA's

Figure III-12
RCE Functional Schematic

Table III-4
Spacecraft Motion Versus Thrusters

	Atlas Coordinates			Spacecraft Coordinates		
Thruster	Roll (X)	Pitch (Y)	Yaw (Z)	Yaw (X)	Roll (Y)	Pitch (Z)
1		+	+	+	+	
2		+	-	-	+	
3		-	-	-	-	
4		-	+	+	-	
5		-	-	-	-	
6		-	+	+	-	
7		+	+	+	+	
8		+	-	-	+	
9	-	+	-	-	+	+
10	+	-	+	+	-	-
11	-	-	+	+	-	+
12	+	+	-	-	+	-
10&12	+					-
9&11	-					+
1&2 or 7&8*		+				
3&4 or 5&6*		-				
1&4 or 6&7*			+			
2&3 or 5&8*			-			
1&2 or 7&8*		+			+	
3&4 or 5&6*		-			-	
1&4 or 6&7*			+	+		
2&3 or 5&8*			-	-		

* Not used on orbit.

the outlet of each hydrazine propellant tank are fired to isolate the hydrazine thrusters from the propellant tanks and render the units inoperative.

Data Handling Subsystem. The Data Handling Subsystem (DHS) is composed of a low-rate instrument and housekeeping telemetry processor called the TIROS Information Processor (TIP), a high-rate Manipulated Information Rate Processor (MIRP), five digital tape recorders (DTRs), and a cross-strap unit (XSU), which routes data between the DTRs, the processors, and each of the communications subsystem data transmitters. The TIP and MIRP generate the data formats described in section D.

TIP outputs either of four modes: "boost" for special telemetry required during launch and ascent; "normal," containing low-rate instrument and housekeeping data; "dwell," for continuously monitoring one telemetry point; and "dump," for telemetering satellite computer-memory contents following a memory load. Input data to the TIP are time-division multiplexed into a format determined by a program stored in a Read Only Memory (ROM) internal to the TIP. The MIRP generates the remaining four formats: Global Area Coverage (GAC), Local Area Coverage (LAC), HRPT, and APT. It incorporates algorithms for data processing and data compression, and contains large multiaccess buffer stores that time-average the intermittent AVHRR Earth-scan input (thereby achieving a bandwidth reduction), and manipulate the AVHRR signals together with TIP data into the desired digital formats. These algorithms are described in more detail in section D.

Five identical tape recorders are used to store data, each consisting of two 4.5 by 10^8 bit capacity transports, and one electronics unit. Operationally, two recorders are generally dedicated to recording GAC for up to four orbits (during blind-orbit conditions) and two to recording selective LAC data. One is a standby (redundant) unit. Two recorders can be played back at the highest rate in parallel, if desired, via two of the three S-band data links, leaving the third link for real-time HRPT data. The XSU, in addition to providing route switching, is the synthesizer and source for all clock signals required by the DHS and the instrument payload. It provides maximum flexibility in routing to the extent that all recorders are functionally interchangeable, both in terms of the data stored and the S-band transmitter to which they can output. A block diagram of the DHS, showing its interrelationship with the communications subsystem (CS), is illustrated in figure III-13.

Communications Subsystem. The CS is composed of:

- One command link at VHF
- Three S-band data links
- Two real-time VHF telemetry links
- Two real-time VHF APT links
- Four VHF/UHF SAR uplinks
- One UHF DCS uplink
- One L-band SAR downlink
- One S-band telemetry link (used during launch and ascent phases)

The 15 individual RF links, and the hardware components associated with these links, are identified in figure III-13. Although the DCS and SAR transceivers are part of the instruments, their antennas and associated feed elements are fur-

Figure III-13
Communication and Data Handling Subsystem
Block Diagram

nished by RCA, and are considered part of the CS. The VHF command receiver is a redundant unit. All other noninstrument-related components are basically functionally redundant. The three S-band data transmitters are interchangeable operationally (except with regard to antenna polarization), and either one of the two pairs of VHF transmitters associated with real-time telemetry [the Beacon Transmitters (BTXs)] and APT (the VTXs) can be selected for their respective data streams. Counting the SAR nested-helix receiving antenna system as a single unit, the subsystem is composed of 10 individual antennas, seven transmitters, and two receivers, together with associated filters and other RF feed components. Three 7 W S-band transmitters (STX 1, 2, and 3) and three directional S-band antennas (SBA 1, 2, and 3) mounted on the satellite Earth-facing +X surface provide the three principal S-band data links. VHF omni coverage for command and real-time TIP telemetry is provided by a dual command receiver/demodulator (CRD) and two 1 W beacon transmitters (BTX 1 and 2) operating through an omni antenna also mounted on the +X face of the satellite. The two APT 5 W VHF real-time transmitters (VTX 1 and 2) use a separate dedicated helical antenna. This, like the instrument-dedicated antennas (the UDA, SLA, and SRA), is also directional, Earth-face mounted, and only used in mission mode. The UDA, SRA, and VRA are deployable. The SRA developed on the ATN program is a unique design incorporating two nested helices: the outer element serves the 121.5 MHz and 243 MHz link, the inner one the 406.05 MHz link. The fourth, SAR uplink (406.025 MHz), is combined with the DCS uplink and is received via the UDA. The performance of all transmitters meets all GSFC specification S-480-16A requirements.

Command and Control Subsystem. The Command and Control Subsystem (C&CS) decodes and validates ground commands that have been received and demodulated in the CS; it then transforms these commands into control or driving signals as appropriate. The C&CS can store certain commands for execution at a later time. It has the flexibility to process and distribute uplinked data as well as discrete signals. It furnishes timing signals to various satellite units, and also provides a computational capability, in conjunction with the flight software, to meet the signal-processing needs of the ADACS. The C&CS is composed of two CPUs, a CIU and its extension (CXU), a SCU, and RXO. The control power converter (CPC), a part of the power subsystem, is housed within the CIU. A block diagram of the C&CS is shown in figure III-14.

Each of the two CPUs contains the satellite main memory and facilities for interfacing with the memory, and for performing arithmetic and logical operations. The major sections are the memory, arithmetic and logic unit (ALU), memory address generator (MAG), and control. I/O interface logic allows the

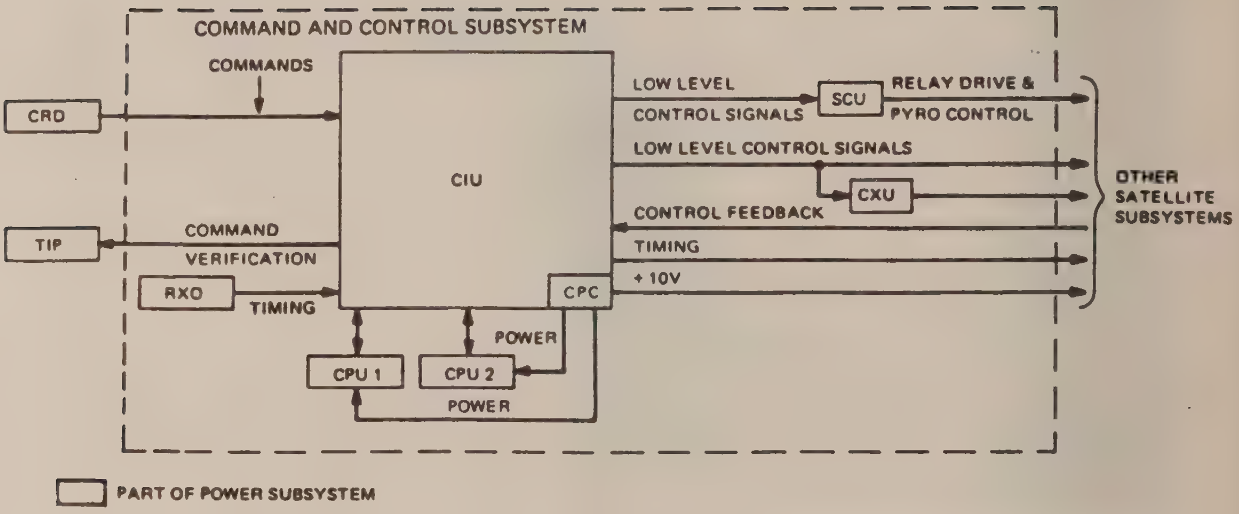

COMMAND AND CONTROL SUBSYSTEM
COMMANDS
CRD
CIU
TIP
COMMAND
VERIFICATION
RXO
TIMING
CPC
CPU 1
CPU 2
POWER
POWER
LOW LEVEL
CONTROL SIGNALS
SCU
RELAY DRIVE &
PYRO CONTROL
LOW LEVEL CONTROL SIGNALS
CXU
CONTROL FEEDBACK
TIMING
+ 10V
OTHER
SATELLITE
SUBSYSTEMS
PART OF POWER SUBSYSTEM

Figure III-14
Command and Control Subsystem Block Diagram

CPU to transmit data and address words to the CIU, and to receive status and data words from the CIU. Each CPU has two memory boards that house 16K words. The 32K computer has single-error correction and double-error detection that features both technical superiority and cost effectiveness. This design is identical to the unit developed on DMSP, and has resulted in a substantial savings to the government.

The CPU uses a multitasking approach, with executive control provided by a configuration of hardware and software. Some tasks are invoked by synchronous or asynchronous hardware interrupts. Other tasks are scheduled by software executive control, based on the state of the system and the external commands. To transfer data and distribute commands, the CPU interfaces with the satellite through the CIU via a set of two buses. Most functions are redundant (on each of the two buses), and either CPU can be placed on either bus. Thus, all functions can be accomplished either directly or by switching buses. A hardware "watchdog" system in the CIU will transfer control away from a CPU if it does not report "OK" on a periodic basis. This system is designed to detect both temporary and permanent faults. In the event of a fault in one CPU, all operations, both on-line and standby, can be performed by the remaining CPU.

The SCU performs three types of signal conditioning. Low-level control signals are converted to medium-power coil-driving output signals (up to 1.5 A at +28 V). Low-level control signals are converted to high-current output signals for firing ordnance devices requiring 4.5 A or less all-fire current; this power is taken from the satellite unregulated battery bus. Status signal conditioning circuits convert low-level inputs to low-level outputs compatible with the CIU, the TIP, and the satellite umbilical.

Flight Software. The flight software is an integral part of the satellite system, and performs critical tasks in all phases of the mission. The satellite CPUs contain identical load packages that execute all functions associated with both launch and ascent, and the on-orbit operational mission. The software is composed of a number of interrelated modules that can be grouped in four broad categories:

- Ascent guidance
- Attitude control
- Command and control
- Executive

The Ascent Guidance Software (AGS) performs the prelaunch functions of alignment, and controls the activation test, the navigation test, and the dynamic closed-loop system tests for both the Atlas and ATN flight phases. AGS performs the in-flight functions of open-loop sequencing, autopilot control, navigation, closed-loop guidance, and telemetry data formatting.

Attitude Determination and Control Software provides for Earth acquisition and determination and control of spacecraft attitude during the orbit phase of the mission. Attitude information from the Earth and sun sensors and the inertial measurement unit is processed with ground-supplied ephemeris data to provide control requirements for the reaction wheels, torquing coils, and thrusters. This software also provides control for the SAD.

Command and Control Software processes real-time and stored commands, formulates orbit-mode computer telemetry, and collects memory-dump data.

The Executive Software provides operating mode control of the two computers, and performs background checks of memory and instruction execution. The Executive Software provides common processing for each interrupt level. It also provides for a "safe state" configuration of the spacecraft, and for monitoring and controlling of the Power Subsystem. Table III-5 summarizes memory usage per subsystem.

Table III-5
Software Sizing by Subsystem

Subsystem Software	Code	Data
Command and Control (C&CS)	2249	2476
Attitude Determination and Control (ADACS)	4288	885
Ascent Guidance Software (AGS)	4081+104*	696
Executive (EXEC)	2937+557*	1272
Power Management Software (PMS)	594	271
Ground Test Software (GTS)	385	13+637*
Total	14,534**	5,613**

* Shared memory with stored command table

** Total memory usage 20,147 words

RCA develops and tests the flight software on a dedicated upgraded software development facility designated as a Multiprocessor Software Development Facility (MSDF).

Electrical Power Subsystem. Electrical power is provided by a boost discharge DET system (fig. III-15). The primary power source is a single-axis-oriented solar array, and the secondary source is a set of three nickel-cadmium batteries. The Electrical Power Subsystem output is regulated +28 Vdc, regulated +5 Vdc, and ± 10 V. The major components are the solar array, batteries, PSE, BCX, PC, SAD, ADE, and the CPC.

In mission mode, the SAD (controlled by the ADE) rotates the solar array, which is canted at 36 degrees to the orbit normal, once per orbit so that it continually faces the sun. The solar array supplies current through slip rings in the SAD to the PSE during normal daytime operation. Power above that required by satellite loads and battery charging is dissipated by partial shunts, which are located on the array so as to dissipate the excess power outside the main modules of the satellite. Total orbit average load capacity for the system is a minimum of 551 W (end of life) after 2 years. The three batteries (each having a capacity of 26.5 A-h) supply power through the boost regulator during the dark portions of each orbit, and augment the solar array for peak-load conditions during daylight portions.

Each battery consists of two battery packs. A mode controller senses the +28 Vdc regulated bus voltage and operates the partial shunts and charge regulator as required. The power converters derive +5 Vdc and +10 and -10 Vdc regulated power (which are used to power interface circuits) from the +28 Vdc regulated power. Automatic switchover in the PSE occurs from primary to backup circuitry for the boost regulator, charge regulator, and mode controller in response to signals from failure-detection circuits. Either primary or backup circuits may be selected by ground command. Commandable battery charge-and-discharge disconnect relays are provided. Full circuit redundancy also exists in the power converter, ADE, and partial shunts. The +5 Vdc power converter also has the built-in logic to automatically switch from primary to backup converter in the event a problem is sensed by the failure detection circuitry.

Thermal Control Subsystem (TCS). The TCS consists of active and passive thermal control equipment. The TCS maintains unit temperatures within the specified operating range, generally within limits of 5 to 25 °C.

Passive thermal control is effected by the appropriate use of multilayer insulation blankets, aluminized teflon thermal shielding, special finishes, and thermal-conduction-control

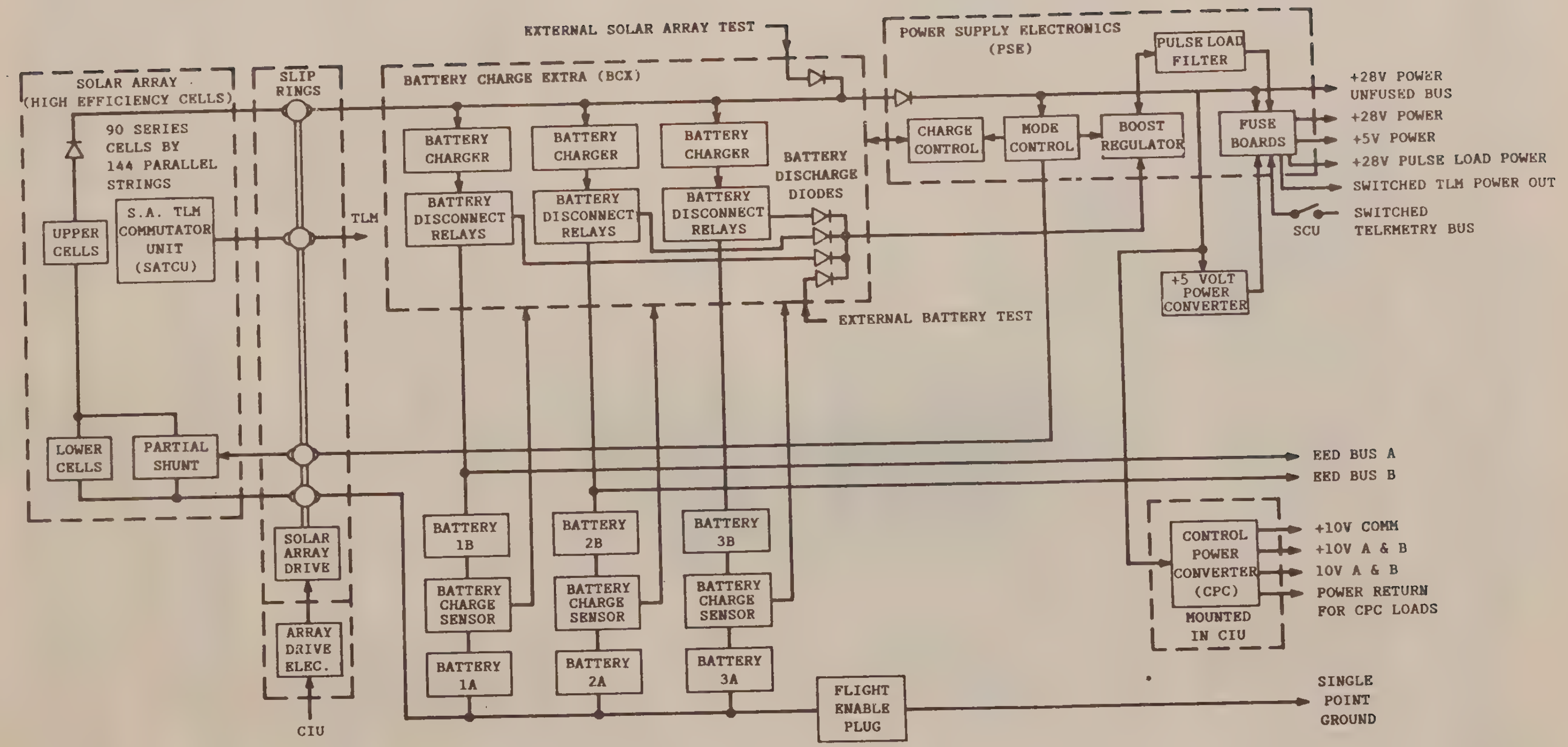

SOLAR ARRAY
(HIGH EFFICIENCY CELLS)
90 SERIES CELLS BY 144 PARALLEL STRINGS
UPPER CELLS
S.A. TLM COMMUTATOR UNIT (SATCU)
LOWER CELLS
PARTIAL SHUNT
SLIP RINGS
TLM
SOLAR ARRAY DRIVE
ARRAY DRIVE ELEC.
CIU
EXTERNAL SOLAR ARRAY TEST
BATTERY CHARGE EXTRA (BCX)
BATTERY CHARGER
BATTERY CHARGER
BATTERY CHARGER
BATTERY DISCONNECT RELAYS
BATTERY DISCONNECT RELAYS
BATTERY DISCONNECT RELAYS
BATTERY DISCHARGE DIODES
EXTERNAL BATTERY TEST
BATTERY 1B
BATTERY 2B
BATTERY 3B
BATTERY CHARGE SENSOR
BATTERY CHARGE SENSOR
BATTERY CHARGE SENSOR
BATTERY 1A
BATTERY 2A
BATTERY 3A
FLIGHT ENABLE PLUG
POWER SUPPLY ELECTRONICS (PSE)
CHARGE CONTROL
MODE CONTROL
BOOST REGULATOR
PULSE LOAD FILTER
FUSE BOARDS
+5 VOLT POWER CONVERTER
SCU
+28V POWER UNFUSED BUS
+28V POWER
+5V POWER
+28V PULSE LOAD POWER
SWITCHED TLM POWER OUT
SWITCHED TELEMETRY BUS
EED BUS A
EED BUS B
CONTROL POWER CONVERTER (CPC)
MOUNTED IN CIU
+10V COMM
+10V A & B
10V A & B
POWER RETURN FOR CPC LOADS
SINGLE POINT GROUND

Figure III-15
Electrical Power Subsystem Block Diagram

materials. The major active elements of the TCS are heaters and louver-controlled cooling radiators. There are two types of louvers (vane louvers and pinwheel louvers), all controlled by TCE units. The satellite incorporates a safe-state mode of operation where, in the event of a major anomaly such as loss of proper attitude, a powered-down state is automatically entered. Under this condition, TCS heaters maintain critical satellite equipment, such as the instruments, at a safe temperature until mission operations can be reestablished.

Structure. The satellite structure is composed of four major elements: the RSS, the ESM, the IMP, and the SA. The IMP is the primary mounting surface for the Earth-viewing instrument payload. As such, it carries the AVHRR, the SSU, and the HIRS. It also mounts the SSD, the ESA, and the IMU. It is fabricated from machined solid aluminum, and is supported in a manner such as to prevent distortion due to satellite main body thermally induced deflections. The ESM structure consists of six honeycomb panels covering a riveted, machined-member, aluminum-alloy frame. The Earth-viewing face of this module is used to support antennas and instruments. The electronic equipment is mounted on the internal sides of all six panels. The ESM structure is connected to the RSS by a titanium-alloy truss arrangement, which encloses the upper portion of the solid rocket engine.

The RSS carries the RCS equipment as well as the battery packs, the ADE, and the BCX. It is of aluminum skin/stringer construction, and provides the primary interface between the satellite and the launch vehicle. The solar array is a single-axis, sun-tracking array with an area of 11.625 m^2. It is composed of eight hinged honeycomb panels. Prior to deployment, the array is wrapped around the main body of the ESM and held in place by two tensioned cables that are cut and fly away upon commanded release. After deployment, the array is supported from the RSS through its main boom, SAD, and array mast. The UDA, SRA, and VRA are stowed during launch and injection, and deployed after orbit is attained. Each of these antennas has its own deployment mechanism.

b. Aerospace Ground Equipment. The Advanced TIROS-N Aerospace Ground Equipment (ATNAGE) used for the present ATN program is being updated in the following manner, and will be designated ATNAGE II. ATNAGE II includes the hardware and software necessary to perform testing and evaluation of data from the TIROS, Advanced TIROS, and POES satellites during system integration and launch. There are two ATNAGE II systems, each consisting of three Data General computers and associated peripherals. In addition, the ATNAGE includes a computer controlled spacecraft simulator and off-line processor, each using a single Data General computer. A brief description of each of the major components of the ATNAGE is contained in the following paragraphs.

The current version of the ATNAGE consists of a series of Data General (DG) Eclipse S/200 and S/230 computer systems with general-purpose input/output (I/O) loads to handle telemetry input processing, high-rate instrument (HRI) processing, and other special processing. Three computers are used in the system, designated computers A, B, and C. These computers function as follows:

- Computer A is a DG S/200 dedicated to running HRI software analysis. All control comes from, and all analysis results go to, computer B.

- Computer B is also a DG S/200. The satellite bus and system control software resides in the foreground of computer B. All telemetry ingest, TIP telemetry limit checking, command verification, and command generation take place in this computer. Computer B also sends low-rate data to, and receives messages from, computer C. Computer B also controls and receives messages from computer A. All operator control inputs go through computer B. The Atlas run-time system is used in the performance of all Atlas-controlled test procedures, and resides in the background of computer B.

- Computer C is a DG S/230. All low-rate instrument (LRI) software analysis for the MSU, SSU, DCS, SEM, HIRS, SAR, ERBE-S, ERBE-NS, and SBUV instruments is performed in computer C.

The ATNAGE II, while maintaining the same basic system architecture as the current ATNAGE, will utilize DG MV8000C computers. This change will provide a system that is maintainable through the mid 1990's.

The spacecraft simulator used in the ATNAGE II is controlled by a Data General MV8000C computer. It includes RF generators to simulate spacecraft transmitters and command receivers, and the necessary control and I/O circuitry to permit it to transmit simulated TIP and high rate data, and receive and decode command data. This capability is used to evaluate the ATNAGE system's readiness, troubleshoot problems, and serve as a software development tool.

3. Bus Comparison

The DMSP and POES buses have been described in detail in previous sections. This section will examine the two buses, and compare each on a subsystem by subsystem basis. Figure III-16 is an overall view of the nine bus subsystems, and table III-6 is a more detailed comparison of each subsystem. The nine subsystems described are:

- Flight software
- Communication
- Command and Control
- Data handling
- Attitude Control
- Power
- Propulsion
- Structure
- Thermal

a. Flight Software. The flight software is an integral part of the satellite system and performs critical tasks in all phases of the mission. The satellite CPUs contain identical load packages that execute all functions associated with both launch and ascent and the on-orbit operational mission. The software is composed of a number of interrelated modules, which can be grouped in four broad categories:

- Command and Control
- Attitude control
- Ascent Guidance Software (AGS)
- Executive

The AGS performs the prelaunch functions of alignment, and controls the activation test, the navigation test, and the dynamic closed-loop system tests for both the booster and the satellite flight phases. AGS performs the in-flight functions of open-loop sequencing, autopilot control, navigation, closed-loop guidance, and telemetry data formatting.

Attitude determination and control software provides for Earth acquisition and determination, and control of spacecraft attitude during the orbit phase of the mission. Attitude information from the Earth and sun sensors, and the inertial measurement unit, are processed with ground-supplied ephemeris data to provide control requirements for the reaction wheels, torquing coils, and thrusters. This software also provides control for the solar array drive.

Command and Control software processes real-time and stored commands, formulates orbit-mode computer telemetry, and collects memory-dump data.

The executive software provides operating mode control of the two computers, and performs background checks of memory and instruction execution. The executive software provides common processing for each interrupt level. It also provides for a

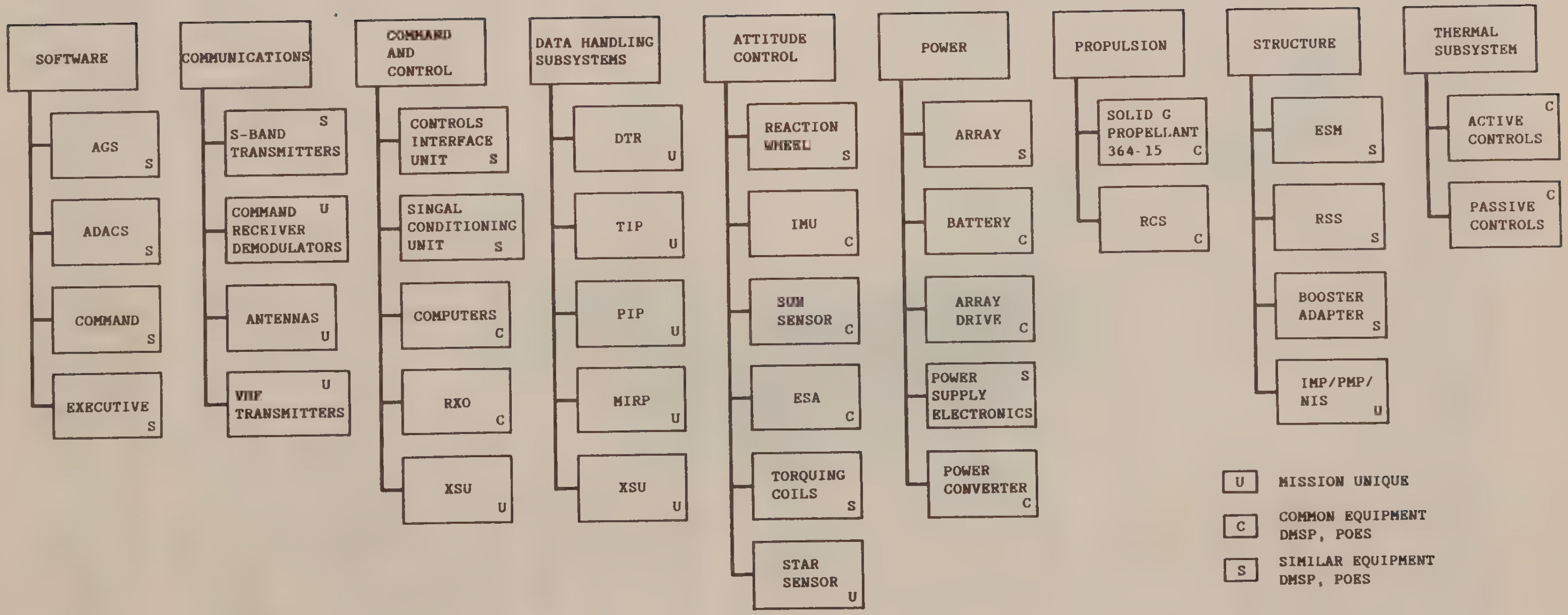

SOFTWARE
AGS S
ADACS S
COMMAND S
EXECUTIVE S
COMMUNICATIONS
S-BAND TRANSMITTERS S
COMMAND RECEIVER DEMODULATORS U
ANTENNAS U
VHF TRANSMITTERS U
COMMAND AND CONTROL
CONTROLS INTERFACE UNIT S
SINGAL CONDITIONING UNIT S
COMPUTERS C
RXO C
XSU U
DATA HANDLING SUBSYSTEMS
DTR U
TIP U
PIP U
MIRP U
XSU U
ATTITUDE CONTROL
REACTION WHEEL S
IMU C
SUN SENSOR C
ESA C
TORQUING COILS S
STAR SENSOR U
POWER
ARRAY S
BATTERY C
ARRAY DRIVE C
POWER SUPPLY ELECTRONICS S
POWER CONVERTER C
PROPULSION
SOLID G PROPELLANT 364-15 C
RCS C
STRUCTURE
ESM S
RSS S
BOOSTER ADAPTER S
IMP/PMP/NIS U
THERMAL SUBSYSTEM
ACTIVE CONTROLS C
PASSIVE CONTROLS C
U MISSION UNIQUE
C COMMON EQUIPMENT DMSP, POES
S SIMILAR EQUIPMENT DMSP, POES

Figure III-16
Subsystem Commonality (DMSP/POES)

Table III-6
Bus Heritage and Growth

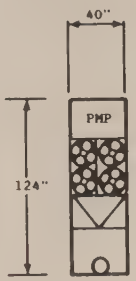
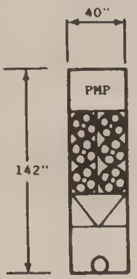
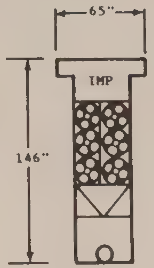
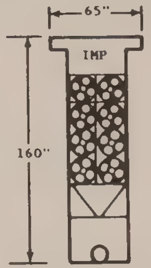
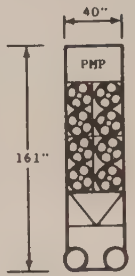
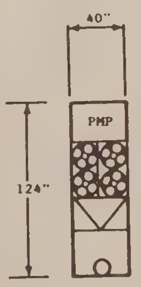
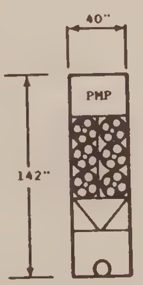
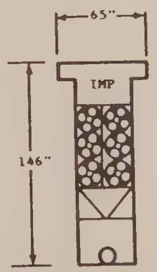
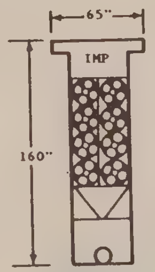
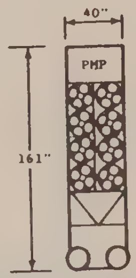
	 5D-1	 5D-2	 TIROS-N	 ATN/POES	 DMSP (5D-3)
TECO WEIGHT (LBS)	1131	1380 1850	1680	1835-2250 ↓ 2470-2900	1697 ↓ 2470
FIRST STAGE	LV-2F	ATLAS F	ATLAS F	ATLAS F	TITAN-2
SECOND STAGE	TE-M-364-4	NONE	NONE	NONE	NONE
THIRD STAGE	TE-M-364-15	TE-M-364-15	TE-M-364-15	TE-M-364-15	TE-M-364-15
N_2H_4 (LBS)	35	35	35	35	35
POWER (WATTS) • BOL (ARRAY OUTPUT) • EOL (LOAD CAPABILITY)	 770 300	 910 400	 1095 465	 1270 520	 1300 600
SUN ANGLE	0°-95°	0°-95°	0°-68°	0°-68°	0°-95°
PAYLOAD WEIGHT (LBS)	300	400 ↓ 650	650	808	650 ↓ 1285
NO. OF BATTERIES	1	2	2	3	3
NO. AND SIZE OF SOLAR PANELS	8 (6'x2')	8 (7.5'x2')	8 (7.5'x2')	8 (7.5'x2')	10 (7.5'x2')
FAIRING DIAMETER (FT)	5	7	7	7	10

Table III-6 (concluded)
Bus Heritage and Growth

	 5D-1	 5D-2	 TIROS-N	 ATN/POES	 DMSP (5D-3)/STS
ADACS • POINTING & CONTROL	0.01°	0.01°	0.1°	0.1°	0.01°
• CONTROL METHOD	RWA & COILS	RWA & COILS	RWA & COILS	RWA & COILS	RWA & COILS
• DETERMINATION SENSORS	CSA, SSA ESA, IMU	CSA, SSA ESA, IMU	SSA ESA, IMU	SSA ESA, IMU	CSA, SSA ESA, IMU
• MODES	PRIMARY BACKUP GYRO COMPASS GN_2 MULS	PRIMARY BACKUP GYRO COMPASS GULS	BASIC GYRO COMPASS GN_2 MULS	BASIC GYRO COMPASS GN_2 MULS	BASIC GYRO COMPASS GULS
COMPUTERS	2	2	2	2	2
MEMORY	16K WORDS	28K WORDS	18K WORDS	18K WORDS TO 34K WORDS	64K WORDS
TECH	CMOS BULK PMOS	CMOS BULK & SOS & PMOS*	CMOS BULK & SOS & PMOS*	CMOS BULK & SOS & PMOS*	CMOS BULK & SOS

* REPLACED WITH CMOS

"safe state" configuration of the spacecraft, and monitoring and control of the power subsystem. Table III-5 summarizes memory usage per subsystem.

The software structure for POES and DMSP is identical. Most of the modules are similar, and some of the codes are identical.

b. Communications. The communication systems of DMSP and POES are nearly identical. POES differs from the DMSP bus primarily due to the use of VHF for uplink and some downlink on POES. The S-band transmitters are very similar.

c. Command and Control. The Command and Control subsystems are very similar for the two programs. They use the same RXO, and each uses two 32K word fault tolerant computers. They have similar control interface units (many of the boards are identical). The signal conditioning unit is similar (some identical boards). The CXU is unique to POES, but is merely an extension of the design utilized in the CIU.

d. Data Handling Subsystem. The POES and DMSP data handling subsystems are unique because of the heavy dependence on sensor interfaces and data rates.

e. Attitude Control. The bulk of the ADACS is common. The IMU for DMSP and POES are identical. The celestial assembly is unique to DMSP, and is not required for POES. The ESA is identical for all programs. The RWA is identical for POES and DMSP.

f. Power Subsystem. This subsystem is essentially the same for the two programs. Where there are differences, they result from enhancements on that program; therefore, the subsystem can be described as the same basic design with substantial common hardware and some components having additional capability. For example:

- The solar arrays are the same design, differing only in the number of panels, solar cell type (standard vs high efficiency), and shunts (single or redundant circuits).
- The batteries differ only in the number used.
- Power supply is the same design and utilizes extensive common hardware.
- CPC is common.
- SAD and array drive electronics are 95 percent common.

g. Propulsion Subsystem - RCE. This subsystem is nearly common on the two programs, with the difference being the size of the tubing to support the different sizes of the RSS.

h. Structure Subsystem. The bus structures are composed of four major elements: the RSS, the ESM, the Sensor Platform (i.e., the IMP for POES, the PMP for DMSP), and the solar array. The IMP/PMP is the primary mounting surface for the Earth-viewing instrument payload. As such, it carries the sensors. It also carries the Sun Sensor Detector (SSD), the ESA, and the IMU. It is fabricated in a manner such as to prevent distortion due to satellite mainbody thermal-induced deflections. The ESM structure consists of six honeycomb panels covering a riveted, machined-member aluminum-alloy frame. The Earth-viewing face of this module is used to support antennas and instruments. The electronic equipment is mounted on the internal sides of all six panels. The ESM structure is connected to the RSS by a titanium-alloy truss arrangement, which encloses the upper portion of the solid rocket engine. Except for the sensor platforms, this equipment is similar on the three programs.

i. Thermal Subsystem. The thermal subsystems for the two programs are common, varying only in quantity of components used.

j. Weight. Table III-2 lists the weight for the two subsystems, broken down by subsystems, and including the payload weights and margins.

k. Bus Heritage and Growth. Table III-6 lists the bus heritage and growth for the POES program. The POES buses have been in production at RCA since 1972, beginning with the DMSP block 5D-1, which RCA won in a competitive procurement. In 1974 the bus evolved to the block 5D-2 and TIROS-N, and subsequently to the Advanced TIROS-N and 5D-3s. Twenty-five of these have been or are being fabricated, and 13 have been launched. There were two launch failures. The 11 that achieved orbit have provided over 30 years of operation to date.

B. SENSOR COMPLEMENTS

As already described in previous sections, there are many common elements on the POES and DMSP buses. There are also many components that are similar, e.g., a once-common box that has been modified for the unique requirements of the particular program. The drivers for unique components are the mission requirements and their associated payloads. Table III-7 provides a list of those elements of the payloads that are carried by the POES and DMSP buses.

Table III-7
POES/DMSP Sensor Comparison

	Spacecraft	Basic Resolution	Sensitivity (min) ($W/cm^2/sr$)	Aperture Diameter (in)	Scan Mode	Scan Angle (deg)	Weight (lb)	Power (W)
Imagers								
OLS 0.4- 1.0 μm 10.2-12.8 μm	DMSP	0.67 mrad	10^{-9}	8	Osc. 5.94 Hz	±56.24	55	9
AVHRR 0.55 - 0.9 μm 0.725- 1 μm 10.5 -11.5 μm 3.55 - 3.93 μm	POES	1.3 mrad	5×10^{-4}	8	Rotating	125.5	60	26.4
SSM/I	DMSP	25 km	N/A	N/A	Rotating	102 Active	125	45
Temperature Sounders (Microwave)								
SSM/T 7 channels 50.5-59.4 GHz	DMSP	12° (180 km)	0.3-0.5	7	7 Steps	± 36	25	18
MSU 4 channels 50.3-57.9 GHz	POES	7.5°	0.3	2-4	11 Steps 9.5 ea.	± 47.4	73.6	31.7

Table III-7 (continued)
POES/DMSP Sensor Comparison

		Spacecraft	Basic Resolution	Sensitivity (min) ($w/cm^2/sr$)	Aperture Diameter (in)	Scan Mode	Scan Angle (deg)	Weight (lb)	Power (W)
SSH		DMSP	2.7°		3	25 Steps	± 48	29	8
15 µm CO_2	6Ch								
9.8 µm O_3	1Ch								
12 µm window	1Ch								
18–28 µm H_2O	8Ch								
Total	16Ch								
HIRS		POES	1.4°	0.15 Ch 1–12 0.03 Ch 13–19	5.9	56 Steps 1.8° ea.	± 49.5	73	22.8
15 µm CO_2	7Ch								
Ozone	1Ch								
Window	4Ch								
4.3 µm CO_2	1Ch								
6.7 µm H_2O	2Ch								
Total	20Ch								
SSU 3 channels 14.9 µm		POES	10.1°	.25 Ch 1 .5 Ch 2 1.25 Ch 3	2°	8 Steps	10	40.3	16
DCS		POES	N/A	N/A	N/A	N/A	N/A	41.3	18.9
SSI/E		DMSP	N/A	N/A	N/A	N/A	N/A	16	10
SEM		POES	N/A	N/A	N/A	N/A	N/A	20.6	7.7
SSJ/4		DMSP	N/A	N/A	N/A	N/A	N/A	5.5	0.5

Table III-7 (concluded)
POES/DMSP Sensor Comparison

	Spacecraft	Basic Resolution	Sensitivity (min) (w/cm^2/sr)	Aperture Diameter (in)	Scan Mode	Scan Angle (deg)	Weight (lb)	Power (W)
SBUV 160–400 nm	POES	160 km x 160 km		N/A	N/A	N/A	84.0	12.0
SAR	POES	N/A	N/A	N/A	N/A	N/A	35.6	57.0
ERBE-NS 3 channels 0.2 to 50 μm 5.0 to 50 μm 0.2 to 3.5 μm	POES	83.4 km x 72.8 km			Rotating		70.83	20.7
ERBE-NS 5 channels total 0.2–50 μm 3Ch 0.2–5 μm 2Ch	POES	138° WFOV 66° MFOV			N/A	N/A	81.31	26.2
Classified	DMSP	---	---	---	---	--	--	--

C. ENGINEERING CHARACTERISTICS OF SENSORS

1. DMSP

a. Weight, Dimensions, Data Rate, Power

See table III-8.

b. Mission Sensor Temperature Requirements

See table III-9.

c. Thermal Characteristics. The spacecraft shall provide thermal control of each mission sensor for all sun angles. Life of each mission sensor will nominally be the same as life of the satellite; however, provisions may be made to terminate thermal control of a mission sensor that has been declared to have failed, if such termination results in enhanced performance or reliability of the remaining satellite systems, and provided that thermal interface requirements of the primary sensor, remaining mission sensors, and spacecraft equipment, as well as all other requirements are met.

Radiated heat loss from mission sensors will be primarily through their field of view. Subject to the field of view requirements of the sensor, and provided that all other sensor requirements are met, the spacecraft may attach thermal blankets, fins, heaters, or other passive thermal control devices to the mission sensors.

The spacecraft shall ensure that the temperature of a mutually agreed upon suitable reference point for each mission sensor remains within the limits specified for the life of the satellite (or mission sensors) under all orbital conditions. Thermal gradients on the mounting interface shall not exceed 0.10 °C per inch for the SSH, SSB/A, SSM/T, and SSM/T-2 in any direction. Spacecraft thermal control shall not cause the temperature of a mission sensor to change at a greater rate than 3 °C per hour.

d. Magnetic Characteristics. The total uncompensated residual magnetic moment of each mission sensor shall not exceed 0.1 ampere-turn-meter^2. Each mission sensor shall not create a magnetic moment difference exceeding 0.01 ampere-turn-meter^2 between any modes of operation.

2. POES

The NOAA Polar-orbiting Operational Environmental Satellite sensors have been developed to provide quantitative data that will meet the requirements of a diverse class of users. Passive remote sensing instruments include:

TABLE III-8

ENGINEERING CHARACTERISTICS OF DMSP SENSORS

Sensors	Weight	Dimensions	@ Data Rate	Power Requirements
OLS*	200 lb	30.2 x 12.2 x 13.6"	66 KB/S or 1.33 MB/S or 660 KB/S	170W
SSM/I	121 lb	24 x 20" Antenna 14 x 14 x 16 " Elec.	3276 BPS	45W
SSM/T	25 lb	8 x 12 x 16"	144 BPS	18W
SSM/T-2	30 lb	TBD	324 BPS	30W
SSH	29 lb	7 x 11 x 5.5" Electronics 12.5 x 15.4 x 8.8" Optics	216 BPS	8W
SSI/E, ES	16 lb	6 x 4 x 4" Elec.	1080 BPS	10W
SSJ/4	5.5 lb	5.7 x 5.7 x 6"	360 BPS	0.5W
SSM	TBD	TBD	TBD	TBD
SSB	25 lb	4.9 x 7.8 x 7.1"	360 BPS	15W
SSUV	TBD	TBD	TBD	TBD

@ Mission sensor data included in real-time data stream. All stored mission sensor data are put on tape recorders via OLS sensor processing unit (SPU).

*Glare obstructor required for protection against solar and albedo glare for orbits earlier than 0830 sun local time. GSSA provides glare protection for near noon orbits.

Unlike the AVHRR the OLS includes the data handling and storage capability for the spacecraft.

TABLE III-9

MISSION SENSOR TEMPERATURE REQUIREMENTS

Mission Sensor	Min Temp (deg C)	Max Temp (deg C)
OLS	N/A (thermally isolated from spacecraft)	
SSM/I	5	25
SSM/T, T-2	5	25
SSH	5	20
SSI/ES	0	30
SSJ/4	–20	30
SSM	–10	50
SSB/A	–15	25
SSB/S	–10	45
SSB/X	–5	25
SSUV	TBD	TBD

a. TIROS Operational Vertical Sounder (TOVS). TOVS is a three instrument system consisting of:

- High-Resolution Infrared Radiation Sounder (HIRS/2) - a 20-channel instrument that makes measurements primarily in the infrared region of the spectrum. The instrument is designed to provide data that will permit calculation of the temperature profile from the surface to 10 mbar, water vapor content in three layers of the atmosphere, and total ozone content.

- Stratospheric Sounding Unit (SSU) - an infrared sensing device employing a selective absorption technique to make measurements in three channels. The spectral characteristics of each channel are determined by the pressure in a carbon dioxide gas cell in the optical path. The amount of carbon dioxide in the cells determines the height of the weighting function in the atmosphere. This instrument has been built and furnished by the Meteorological Office of the United Kingdom.

- Microwave Sounding Unit (MSU) - a four-channel Dicke radiometer that makes passive measurements in the 5.5 mm oxygen band.

Characteristics of the instruments comprising the TOVS system are described more fully in chapter V.

b. Advanced Very High Resolution Radiometer (AVHRR/2). This five-channel instrument is sensitive in the visible, near infrared, and infrared window regions.

The AVHRR/2, which is described more fully in chapter IV, provides data for central processing to produce products such as sea surface temperature analyses, snow and ice extent maps, and agriculture indices. This instrument also provides data for real-time transmission to users through the APT and HRPT systems.

c. Solar Backscatter Ultraviolet Radiometer (SBUV/2). The SBUV/2 is a nonspatial scanning nadir viewing instrument designed to measure scene radiance in the spectral region from 160 to 400 nm. The data gathered are used to determine the vertical distribution of ozone in the Earth's atmosphere, total ozone in the atmosphere, and solar spectral irradiance.

To collect this information, two separate measurements in the 160 to 400 nm spectral range are made by the SBUV/2 instrument. These are the spectral radiance of the solar ultraviolet radiation backscattered from the strong ozone absorption band of the Earth's atmosphere, and the direct solar spectral irradiance.

The SBUV/2 instrument is divided into two components, separating the electronics and logic, and the sensor/detector modules. The Earth-viewing sensors are mounted on the exterior surface of the equipment support module of the satellite, while the electronics/logic module is located within.

The basic components of the sensor module are:

- Scanning double monochromator
- Cloud cover radiometer
- Diffuser plate
- Detectors

The SBUV/2 instrument measures backscattered solar radiation in an 11.3 degree field of view in the nadir direction at 12 discrete, 1.1 nm wide, wavelength bands between 252.0 and 339.8 nm. The solar irradiance is determined at the same 12 wavelength bands by deploying, upon command, a diffuser that will reflect sunlight into the instrument field of view. The atmospheric radiance measurement, relative to the solar irradiance, is the significant factor being determined.

The SBUV/2 instrument can also measure the solar irradiance or the atmospheric radiance with a continuous spectral scan from 160 to 400 nm, in increments nominally 0.148 nm. These measurements provide data on photochemical processes in the atmosphere.

A separate narrow band filter photometer channel, called the Cloud Cover Radiometer (CCR), continuously measures the Earth's surface brightness at 380 nm, i.e., outside the ozone absorption band. The CCR is located in the same structure as the monochromator. The CCR field of view is the same size (11.3° by 11.3°) as, and is coaligned with, the monochromator's field of view.

The instrument operates in five distinct modes:

- Discrete Mode. The instrument sequentially measures scene radiance and solar spectral irradiance in 12 discrete spectral bands.
- Sweep Mode. The instrument will sense input energy as the spectral band pass is "swept" 160 to 400 nm in a continuous manner. Each measurement will have an equal integration time and be equally spaced across the spectral band. Either the scene spectral radiance or solar spectral irradiance may be measured in this mode.

- Wavelength Calibration Mode. This is equivalent to the discrete mode, but the spectral wavelengths scanned will be equal to those of the onboard calibration lamp.

- Monochromator Stop Mode. In this mode, the spectral scan is interrupted with the grating fixed in position at the time of command receipt.

- Monochromator Caged Mode. In this mode, the monochromator is caged (for launch) at a predetermined position.

The sequencing for each monochromator mode is controlled from either a fixed, ground-programmable memory, or from a random-access memory, programmable by command. The desired memory is selected by command.

Each monochromator mode defines a unique wavelength sequence and a data sampling sequence. The wavelengths are always scanned from the long wavelengths to the short wavelengths. This is followed by a rapid retrace to the long wavelength and a wait for the start of the next 32 second TIROS Information Processor (TIP) major frame. During this time, the preamplifiers are switched out, and up to 10 precision voltage levels are inserted into the electronics for calibration of the analog electronics and the voltage-to-frequency converters.

Beginning at the start of the first major frame, following a "discrete mode" command, the gratings sequentially move to and dwell at the 12 discrete wavelengths. The signal at each wavelength is integrated for 1.25 seconds. An additional 0.75 second is allowed for moving to and settling at the next wavelength. Thus, the 12 discrete wavelengths are covered in 24 seconds. This allows 8 seconds for returning to the first discrete wavelength, electronic calibration, and waiting for the start of the next major frame.

Beginning at the start of the first major frame following receipt of a "sweep mode" command, the wavelength range from 400 to 160 nm is scanned in nominally 0.074 nm steps. The monochromator signal is integrated for 0.1 second resulting in nominally 0.148 nm sample increments. Therefore, approximately 1,631 spectral measurements are made between 400 and 160 nm. This takes about 164 seconds. The grating drive then retraces to 400 nm and waits for the start of the next major frame. Thus, the total cycle time for the sweep mode is 192 seconds. Electronic calibration takes place during the time period between 164 and 192 seconds.

The "wavelength calibration mode" is functionally very similar to the "discrete mode." Beginning at the start of a major frame, it moves to and dwells at 12 separate wavelengths, each separated by nominally 0.296 nm, around any desired line source. At each wavelength, data are integrated for 1.25 seconds.

d. Space Environment Monitor (SEM). SEM is a two-instrument system consisting of:

- Total Energy Detector (TED) - an instrument that measures a broad range of energetic particles from 0.3 keV to 20 keV in 11 bands. The instrument uses a curved plate analyzer and channeltron detector to determine the intensity of particles in these energy bands. Four curved plate analyzers (two measuring electrons, two protons) measure incoming particles reaching the instrument. Outputs from the analyzers are sent to the detectors and then to the data processing unit for multiplexing into the final output data stream.

- Medium-Energy Proton and Electron Detector (MEPED) - senses protons, electrons, and ions with energies from 30 keV to greater than 60 MeV. This instrument is composed of four directional, solid-state detector telescopes, and one omnidirectional sensor. All five components use solid-state nuclear detectors. Outputs from the detectors are connected to a signal analyzer, which senses and logically selects those events that exceed threshold values. These data are fed to the data processing unit and are included within the system output.

e. Argos Data Collection System (DCS). This random-access system was designed to acquire environmental data from fixed and free-floating terrestrial and atmospheric platforms. Platform location is determined where required by processing of the Doppler measurements of carrier frequencies.

The Argos DCS has been built and furnished by the Centre Nationale d'Etudes Spatiales (CNES) of France. The Argos provides a means for obtaining environmental (e.g., temperature, pressure) data from, and Earth-locating, fixed or moving platforms. Location information, where necessary, may be computed by differential Doppler techniques using data obtained from the measurement of the platform carrier frequency as received on the satellite. When several measurements are received during a given contact with a platform, location can be determined. The environmental data messages sent by the platform will vary in length, depending on the type of platform and its purpose. The Argos DCS system consists of three major components: terrestrial platforms, satellite-borne instrument, and processing center.

- Platforms. The terrestrial platform is developed by the user to meet particular needs, and must meet the interface criteria defined by CNES. Before being accepted for entry into the system, the platform design must be certified as meeting these criteria. By international agreement, entry into the system is limited to platforms requiring location service, or those situated in polar regions out of the range of the DCS on geostationary satellites.

- Satellite-Borne Instrument. The onboard instrument is designed to receive the incoming platform data, demodulate the incoming signal, and measure both the frequency and relative time of occurrence of each transmission. The onboard system consists of: the power supply and command interface unit, the signal processor, and the redundant receiver and search units.

  Platform signals are received by the receiver search unit at 401.65 MHz. Since it is possible to acquire more than one simultaneous transmission, processing channels, called Data Recovery Units (DRU), operate in parallel. Each DRU consists of a phase lock loop, a bit synchronizer, a Doppler counter, and a data formatter. After measurement of the Doppler frequency, the sensor data are formatted with other internally generated data, and the output is transferred to a buffer interface with the spacecraft data processor (TIP).

- Processing Center. Data from the DCS are included with those from the low bit rate instruments within the TIP. After receipt of the stored data at the central processing facility, the DCS information is decommutated and sent to the CNES Argos processing center in Toulouse, France.

f. Search and Rescue Satellite-Aided Tracking (SARSAT) System. SARSAT is a random-access system to obtain signals from aircraft and ships in distress. Location of the transmitting platform is determined by processing the Doppler measurements of carrier frequencies.

The SARSAT system consists of space and ground components. The key elements are:

- A satellite-borne receiver, frequency translation repeater (provided by the Department of Communications, Canada) for both existing and experimental Emergency Locator Transmitter (ELT)/Emergency Position-Indicating Radio Beacons (EPIRB) bands (121.5, 243, and 406 MHz). This system is used for regional coverage/alerting.

- Local User Terminals (LUT), which receive the related

ELT/EPIRB signals, and process the Doppler data to Earth-locate the transmitting platform.

- Operational and experimental ELT and EPIRB systems.
- A satellite-borne receiver and processor for the experimental (406 MHz) ELT/EPIRB transmissions (provided by CNES). The unit is analogous to and, in many ways, equivalent to the DCS, also provided by CNES, and is used to provide experimental data for regional and global purposes.
- Mission Control Centers for coordinating activities, processing global experimental data, and coordinating search activity support.

g. Spacecraft Repeater System. When an emergency occurs to a vehicle carrying an ELT or EPIRB, the unit is activated either automatically or manually. The weak (100 mw) signal transmitted, which is used for homing by search forces, is amplitude modulated, so that it can be recognized by listening to an ordinary communications receiver. With the SARSAT system, the signal is received by the satellite when it is within range of the transmitter. The signal is then translated and rebroadcast to any LUT within view of the satellite. Because of the relative velocity difference between satellite and platform, the signals received at the satellite are Doppler shifted. At the LUT, special processing of the received signals, after time tagging, allows the weak transmission of the Doppler shifted signal to be processed to determine the position of the transmitter. This information is then provided to a Rescue Coordination Center for use in their operations.

h. Experimental 406 MHz System. This system works in the same manner as the DCS. The relatively strong signal (5 W transmitter) is transmitted on a periodic basis. The Doppler-shifted frequency received on the satellite is measured and time tagged. This information is both transmitted in real time at 1544.5 MHz, and stored on board the satellite so that regional and global coverage is obtained. The data received either at the LUT or, through the NOAA ground complex, at the Mission Control Center, are processed to determine platform location, and, through its coded transmission, platform identification. This information is also sent to the Rescue Coordination Center for use in their operations.

D. ONBOARD AUTOMATION OF PROCESSING AND OPERATION

1. DMSP

a. High to Low Resolution Conversion. The OLS is the primary data acquisition system on the DMSP spacecraft. This system gathers, outputs in real time, and stores multiorbit day and night visible and infrared spectrum data from Earth scenes. It provides such data, together with appropriate calibration, indexing, and other auxiliary signals, to the spacecraft for transmittal to ground stations. The data are collected, stored, and transmitted in either fine or smoothed resolution.

Thermal Fine (TF) resolution data are collected continuously, day and night, by the infrared detector; Light Fine (LF) resolution data are collected continuously during daytime only by the silicon diode detector. Fine resolution data have a nominal linear resolution of 0.3 nm. Because of the quantity of data collected, it is not possible to store or to transmit all of the fine resolution information. Therefore, smoothing (as described below) or selective collection is required. Storage capacity and transmission constraints limit the quantity of fine resolution data that can be provided in the Stored Data Fine (SDF) mode to a total of 40 minutes of LF or TF data per 10-minute CRS readout.

Data smoothing permits global coverage in both Thermal Smoothed (TS) and Light Smoothed (LS) data to be stored on the primary tape recorders in the Stored Data Smoothed (SDS) mode. This smoothing is accomplished by analog averaging of the fine resolution input from five resolution cells that are contiguous in the across-track direction, then digitally averaging five such 1 by 5 cell samples in the along-track direction. A nominal linear resolution of 1.5 nm results. During a single 10-minute CRS readout, 400 minutes of LS and TS data may be transmitted.

In addition, a photomultiplier tube allows collection of LS data under quarter-moon or brighter nighttime conditions at 1.5 nm nominal linear resolution.

A combination of either fine resolution data and the complementary smoothed resolution data (i.e., LF and TS or TF and LS) can be provided directly to remote sites in the real-time data (RTD) mode. In this mode, only the analog, across-track smoothing is provided before transmission. Along-track smoothing is done by the ground processing equipment.

b. Automated Control and Ephemeris Generation. The DMSP spacecraft is capable of a high degree of automated control due to its onboard computers and flight software. From daily uplinks of ephemeris, star, and stored command data, it is capable of maintaining precision attitude control, magnetic momentum unloading, and routine ground contacts for downlink. However, without daily uplinks of these data, precision attitude control is rapidly lost and interpolated position from ephemeris data becomes unusable. DMSP has two requirements to improve this situation.

The first requirement is to make DMSP capable of operating for 7 days without ground support. The requirement is driven by the potential for an increased satellite constellation, making it increasingly difficult for the ground system to support the mission. This goal will be accomplished in two phases. Phase I will provide 7 days of operation in the basic attitude control mode by modifying the on-orbit ephemeris software to compensate more accurately for ephemeris data that is more than 24 hours old. Phase II, providing 7 days of precision attitude control, may require the DMSP spacecraft to handle a star catalog containing 7 days of data (currently it contains 1 day), and a totally new way of calculating the ephemeris on orbit. Work has begun on phase I. Work on phase II is being held in abeyance until the performance of phase I can be determined.

The second requirement, to support tactical units with weather data in a post-attack environment, is to provide real-time cloud cover data accurate within 25 nautical miles for 60 days without ground support. This requirement will be accomplished as a side effect of phase I above. In other words, the projected long-term accuracy of phase I should be adequate to meet the 25 nautical mile, 60-day requirement.

Magnetic momentum unloading is not as sensitive as attitude control to ephemeris errors. However, two possible improvements are being considered in this area. First, the integration of a magnetometer to determine, without ephemeris data, when the spacecraft is in a magnetic unloading region. Second, a software solution consisting of regular timed activations of the unloading coils and momentum observation software. If the system detects the spacecraft is in an unloading region, the proper polarity is selected and momentum unloading is accomplished.

c. Data Handling System. Details of the DMSP data handling subsystem of the OLS are contained in DMSP OLS Data Specification, SS-YD-821.

2. POES

a. Subsystem Description. The Data Handling Subsystem (DHS) consists of the components listed in table III-10, interconnected as shown in figure III-17.

The functions of the DHS are to collect, format, average, and store base band data from other satellite subsystems, to output base band data to other satellite subsystems, and to

Table III-10
Data Handling Subsystem Major Component List

Quantity	Name	Performance Specification	Weight	Power	Size
1	TIROS Information Processor	PS-2284374	7.26 kg	6.0 W	33.02x19.3x1.91 cm
1	Manipulated Information Rate Processor	PS-2284391	5.08 kg	11.0 W (maximum)	23.88x19.3x2.03 cm
5	Digital Tape Recorder	IS-2280354	10.35 kg	Mode dependent 21.5 W (maximum)	27.9x17.7x23.88 cm
1	Cross-Strap Unit	PS-2284379	3.81 kg	Mode dependent 13.7 W (maximum)	20.32x19.3x2.03 cm

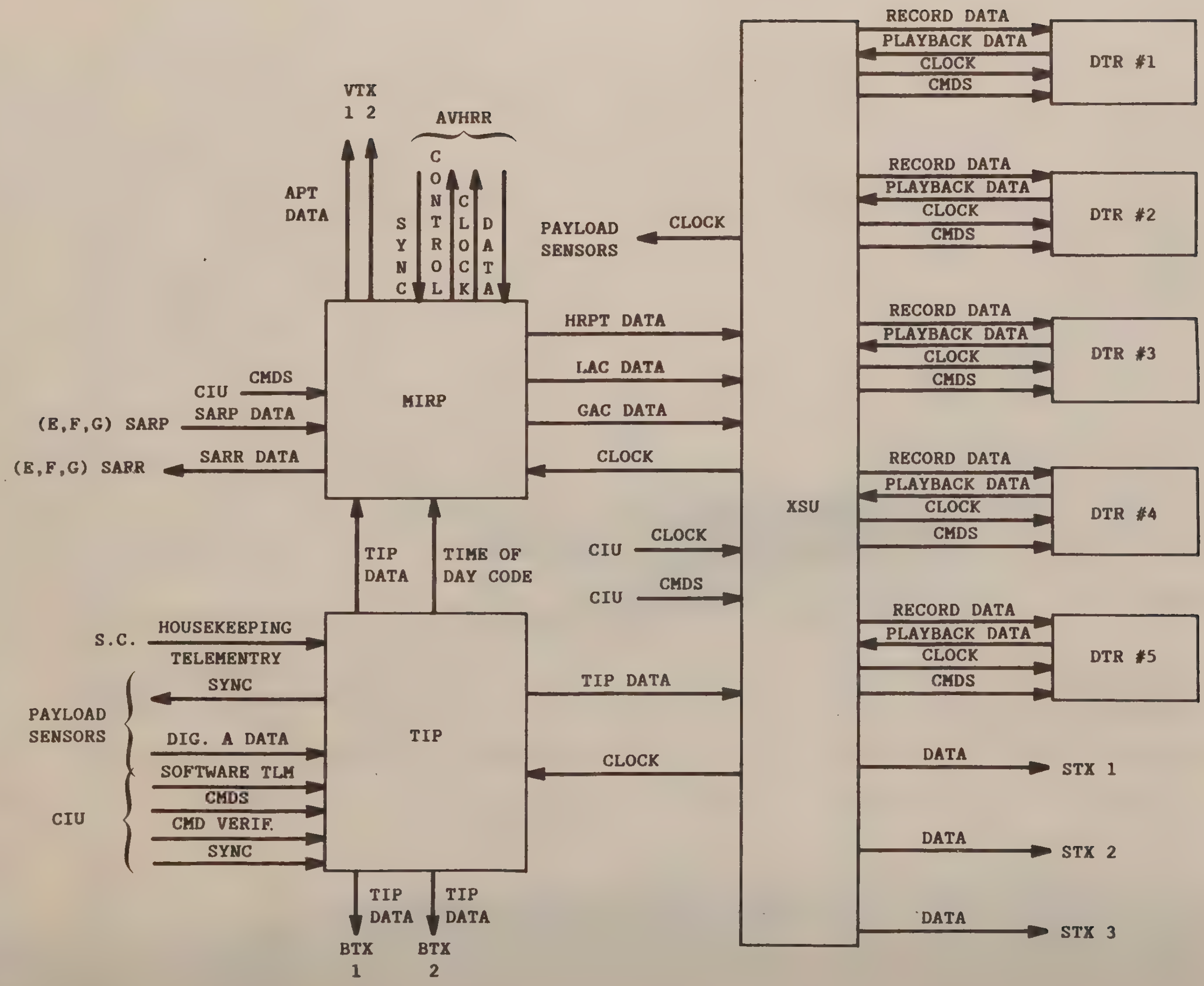

VTX
1 2
APT DATA
AVHRR
SYNC
CONTROL
CLOCK
DATA
PAYLOAD SENSORS
CLOCK
MIRP
CIU
CMDS
(E,F,G) SARP
SARP DATA
(E,F,G) SARR
SARR DATA
HRPT DATA
LAC DATA
GAC DATA
CLOCK
TIP DATA
TIME OF DAY CODE
CIU
CLOCK
CIU
CMDS
XSU
S.C.
HOUSEKEEPING
TELEMENTRY
PAYLOAD SENSORS
SYNC
DIG. A DATA
CIU
SOFTWARE TLM
CMDS
CMD VERIF.
SYNC
TIP
TIP DATA
CLOCK
TIP DATA
BTX 1
TIP DATA
BTX 2
RECORD DATA
PLAYBACK DATA
CLOCK
CMDS
DTR #1
RECORD DATA
PLAYBACK DATA
CLOCK
CMDS
DTR #2
RECORD DATA
PLAYBACK DATA
CLOCK
CMDS
DTR #3
RECORD DATA
PLAYBACK DATA
CLOCK
CMDS
DTR #4
RECORD DATA
PLAYBACK DATA
CLOCK
CMDS
DTR #5
DATA
STX 1
DATA
STX 2
DATA
STX 3

Figure III-17
Data Handling Subsystem Functional Block Diagram

provide sync signals and clocks to other satellite subsystems. The input data, output data, and clock/sync signals are listed in tables III-11 through III-13, respectively. The following paragraphs outline the activities and products of the DHS components. Later sections define the outputs and describe the components in detail.

The redundant TIP collects all housekeeping telemetry for the satellite except during the TIP boost and dwell modes. The TIP also collects all mission payload data except for data from the AVHRR, the Search and Rescue Processor (SARP), and the Search and Rescue Repeater (SARR). It formats the data into a serial binary stream and outputs it to both BTXs, the XSU, and, except in the TIP boost mode, to the MIRP. The TIP maintains one of the satellite's time-of-day clocks and the only satellite day-of-year clock. It formats the clock information into the output stream, and passes it at a higher rate to the MIRP. The TIP furnishes sync signals to all scanning instruments, except the AVHRR, so that they can synchronize their scans with the TIP and each other. The TIP provides the digital-B and digitized analog telemetry parts of its output format to the CIU for logging in the CPU memory. The TIP formats are summarized in tables III-14 and III-15. The TIP cannot be turned off; i.e., one of the redundant sides is always on. The MIRP can be turned on and off by command. It collects radiometric data from the AVHRR, TIP data from the TIP, and time code data from the TIP. It uses the data to produce four output formats simultaneously. The MIRP collects most of the AVHRR data in a burst lasting about 1/3 of each turn of the AVHRR mirror. One function of the MIRP is to buffer the data to obtain a steady output data rate. The MIRP output formats are as follows:

- High-Resolution Picture Transmission (HRPT) and Local Area Coverage (LAC). The HRPT/LAC formats are summarized in table III-16. These are identical in data content and bit rate. The LAC format includes an extra step called "randomization," the purpose of which is described below. The format contains full-resolution AVHRR data, the complete TIP format, and time code. Both formats go to the XSU, which outputs the HRPT format in real time to an S-band Transmitter (STX-1, -2, or -3), as split-phase data. It outputs the LAC format to one of the DTRs, on command, for playback over a CDA station. One of the playback options uses NRZ-L bit structure.

  The LAC format includes randomization to increase the probability of frequent binary transitions, and thereby improve the signal-to-noise performance of the demodulators at the CDA stations. The word "local" in the LAC format stems from the necessity to restrict the duration of LAC recording on the DTRS. The high bit rate of the

Table III-11
Data Handling Subsystem Data Inputs

Name of Data	Source of Data	First Data Handling Component Receiving the Data	Data Characteristics
Analog telemetry	All active electronic components on the satellite - 512 separate channels	TIP	Analog health-monitor voltage on a dedicated wire per quantity
Digital-B Telemetry	Same as above, but 352 separate channels	TIP	Bilevel status voltage on a dedicated wire per quantity
CPU Telemetry-Boost Mode	CIU	TIP	NRS-L data per a specified handshake 8,000 bps
CPU Telemetry-Orbit Mode	CIU	TIP	Same as above, but at 960 bps
Command Verification Data	CIU	TIP	NRZ-L data per a specified handshake One 16-bit word per 0.05 s (Boost) Mode) or 0.1 s (Orbit Mode)
Digital-A Data	All government-furnished instruments except AVHRR, SARR, and SARP (16 channels, 7 used)	TIP	NRZ-L data per a specified handshake In multiples of 6 bits per 0.1 s (Boost Mode) or 0.1 s (Orbit Mode)
AVHRR Data	AVHRR	MIRP	NRZ-L data per a specified handshake In bursts at 1.9968 Mbps, averaging to 0.6213 Mbps

Table III-12
Data Handling Subsystem Data Outputs

Name of Data	Real Time or Playback	Destination	Conditions	Data Characteristics
TIP orbit	Real time	Both BTX's	Tip in orbit mode	8,320-bps split-phase
TIP orbit	Real time	STX-2	Tip in orbit mode command to XSU	8,320-bps split-phase
TIP boost	Real time	STX-2	TIP in boost mode command to XSU	16,640-bps split-phase
HRPT	Real time	One or more STX's	MIRP on command to XSU	665.4-kbps split-phase
APT	Real time	Both VTX's	MIRP on	Amplitude-modulated 24,000-Hz subcarrier
TIP orbit	Playback	One or more STX's	Command to XSU	332.7-kbps split-phase
TIP boost	Playback	One or more STX's	Command to XSU	332.7-kbps split-phase
GAC	Playback	One or more STX's	MIRP on command to XSU	2.6616-Mbps NRZ or 1.3308-Mbps split-phase
LAC	Playback	One or more STX's	MIRP on command to XSU	2.6616-Mbps NRZ or 1.3308-Mbps split-phase
TIP Subcom Data	Real time	CIU	CIU responds to handshake	64 bits per TIP minor frame-in bursts

Table III-13
Data Handling Subsystem Clocks and Sync Signals

	Clocks (MHz)		Sync Signals (once per)				
Destination	0.9984	1.248	TIP Minor Frame	1.0 Second	320 TIP Minor Frames	1280 TIP Minor Frames	2560 TIP Minor Frames
AVHRR	X						
HIRS/2		X		X	X		X
DCS					X		
MSU		X				X	
SEM		X		X	X		
SSU		X		X	X		X
SBUV/2		X		X	X	X	X
SATCU			X		X		

Table III-14
TIP Boost Mode Format Parameters

Parameter	Characteristics
Form of Data	Serial PCM bit stream, 8-bit words, most significant bit first
Bit Rate	16,640 bps
Minor Frame Length	104 words, 0.05 second
Major Frame Length	320 minor frames, 16 seconds

Table III-15
TIP Orbit Mode, CPU Dump Mode, and
Single-Point Dwell Mode Format Parameters

Parameter	Characteristics
Form of Data	Serial PCM bit stream, 8-bit words, most significant bit first
Bit Rate	8,320 bps
Minor Frame Length	104 words, 0.1 second
Major Frame Length	320 minor frames, 32 seconds

Table III-16
MIRP High-Resolution Transmission and Local Area Coverage Format Parameters*

Parameter	Characteristics
Form of Data	Serial PCM bit stream, 10-bit words, most significant bit first
Bit Rate	665,400 bps
Word Rate	66,540 words per second
Minor Frame Length	0.166 second, 11,090 words
Major Frame Length	3 minor frames

*All MIRP operating modes except MIRP test mode

LAC format limits its use to about 1/10 of the time; neither DTR capacity nor available playback time can support full-time LAC records.

- Global Area Coverage (GAC). The GAC format is summarized in table III-17. This format contains reduced-resolution AVHRR data, plus the complete TIP format and time code. The reason for reduced resolution is to overcome the DTR capacity and link/contact limitations that restrict LAC recordings to only a fraction of each orbit. The GAC format goes to the XSU and thence to a DTR on a full-time basis, allowing the CDA stations to recover a complete unbroken record (hence, the "global" in GAC). The MIRP creates the reduced-resolution data from the raw AVHRR data by a combination of discarding some samples and averaging over others.

- Automatic Picture Transmission (APT). The APT format is summarized in table III-18. This format contains AVHRR data plus a minute marker. The AVHRR data are from two of the five AVHRR channels, selected by command. The MIRP outputs the APT format to both VHF transmitters in real time.

The APT format has reduced resolution in order to use the narrow-band VTX downlink. In addition, the format is "geometrically corrected," consisting of more samples of data collected near nadir than data collected near the edge of the Earth. The result is nearly constant 4 km-resolution along the entire 2,900 km swath. The MIRP does the processing digitally,

Table III-17
MIRP Global Area Coverage Format Parameters*

Parameter	Characteristics
Form of Data	Serial PCM bit stream, 10 bit words, most significant bit first
Bit Rate	66,540 bps
Word Rate	6654 words per second
Frame Length	3327 words 0.5 second

*All MIRP modes except MIRP test mode

Table III-18
APT Format Parameters*

Parameter	Characteristics
Form of Data	Analog video signal, amplitude modulating a 2400-Hz subcarrier
Line Length	0.5 second
Frame Length	128 lines, 64 seconds
Word Rate 8 bits (Prior to digital analog conversion)	4160 words per second
Video Bandwidth	2.4 kHz

*All MIRP modes except MIRP input data substitution mode

then converts to an analog waveform, amplitude-modulates a subcarrier with it, and filters the result. APT data are intended exclusively for simple user equipment such as facsimile recorders, hence the analog format, uniform resolution, and geometrical correction in the satellite for the two selected channels.

The redundant XSU switches all inputs to the S-band Transmitters (STXs), switches all inputs, outputs, and routine commands associated with the DTRs, and provides "clocks" (i.e., square waves) to all data handling components and all government-furnished instruments, except for the SARR, SARP, and DCS. XSU synthesizes the clocks from an input from the CIU. One side or the other of the XSU is always on. The DTRs record TIP, LAC, and GAC data. They play back TIP data to the Lannion station, and LAC and GAC data to the CDA stations. DTR performance characteristics are presented in table III-19.

The system of DTRs is sized to meet the following requirements with one failed DTR:

- Recover an unbroken record of GAC data at the CDA stations, with overlap, i.e., with record while playing back

- Recover 10 minutes per orbit (record time) of LAC data at the CDA stations

- Recover TIP playback at Lannion on those orbits that are blind to the CDA stations

b. Ascent Modes (Launch and Early Orbit)

Subsystem Operations. The DHS tasks begin at satellite turn-on on the pad, and end when NASA/NOAA releases the Lannion station from its support of the launch, normally 1 day after final deployment in operational orbit.

The DHS tasks change with the phase of the launch as follows:

- Satellite Turn-On to Deployment in Operational Orbit

  - TIP is in orbit and CPU dump mode during CPU loading, and in boost mode from several hours before launch until the end of this phase.

  - MIRP is ON, providing a pass-through of the clock from the XSU to the AVHRR, which lets the AVHRR mirror rotate to avoid vibration damage to the mirror bearings.

  - TIP real-time data are transmitted through STX-2 throughout this phase.

  - DTRs are OFF until 10 minutes before launch; one DTR is ON, recording TIP data starting at this time, and continuing through the end of this phase.

Table III-19
Digital Tape Recorder Performance Summary

Data	Record Length on Each TU (minimum)*		Playback	
	Minutes	Bits	Ratio	Minutes
TIP Boost	113	1.12×10^8	20:1	5.6
TIP Orbit	225	1.12×10^8	40:1	5.6
LAC	11.3	4.50×10^8	4:1 2:1	2.8 5.6
GAC	113	4.50×10^8	40:1 20:1	2.8 5.6

*Each DTR contains two Transport Units (TU). The data herein refer to each TU.

- Deployment in Operational Orbit Until Release by Lannion
  - TIP is in orbit mode, occasionally switching to CPU dump mode as commanded by the CDA stations in association with CPU load/dump activities. (These formats are described in section C.)
  - MIRP is ON as part of activation and evaluation activities. APT data are output to both VTXs (not commandable; outputs always active when MIRP is ON).
  - TIP data are output to a DTR at all times; a DTR is always recording.
  - TIP real-time data are output to both BTXs (not commandable; outputs always active).
  - DTR playback takes place over CDA stations via STX-1, -2, or -3.

Mode changes in operational orbit are accomplished by real-time command, or stored command, at the convenience of the activation and evaluation planners. The ground contacts are long enough to give them that choice.

Subsystem Formats - Launch and Early Orbits. The DHS produces two formats in launch and early orbit TIP boost, or TIP orbit. This section describes the TIP boost mode format and is depicted in figure 18. The TIP orbit mode format is described above and depicted in figure 19. The major parameters of this format are defined in table III-14.

The following description of this format refers to Figure III-19:

- Sync Word. The TIP outputs the following sequence with the most significant bit first:

Minor Frame Word 0	Minor Frame Word 1	Minor Frame Word 2
11101101 (MSB)	11100010	0000 (LSB)

- Satellite Address. Bits 5 through 8 of word 2 are reserved for identification.

- Command Verification Status. Bit 1 of word 3 indicates that a new command verification (CV) word has been received; "1" means a new CV word, and "0" means no new CV word.

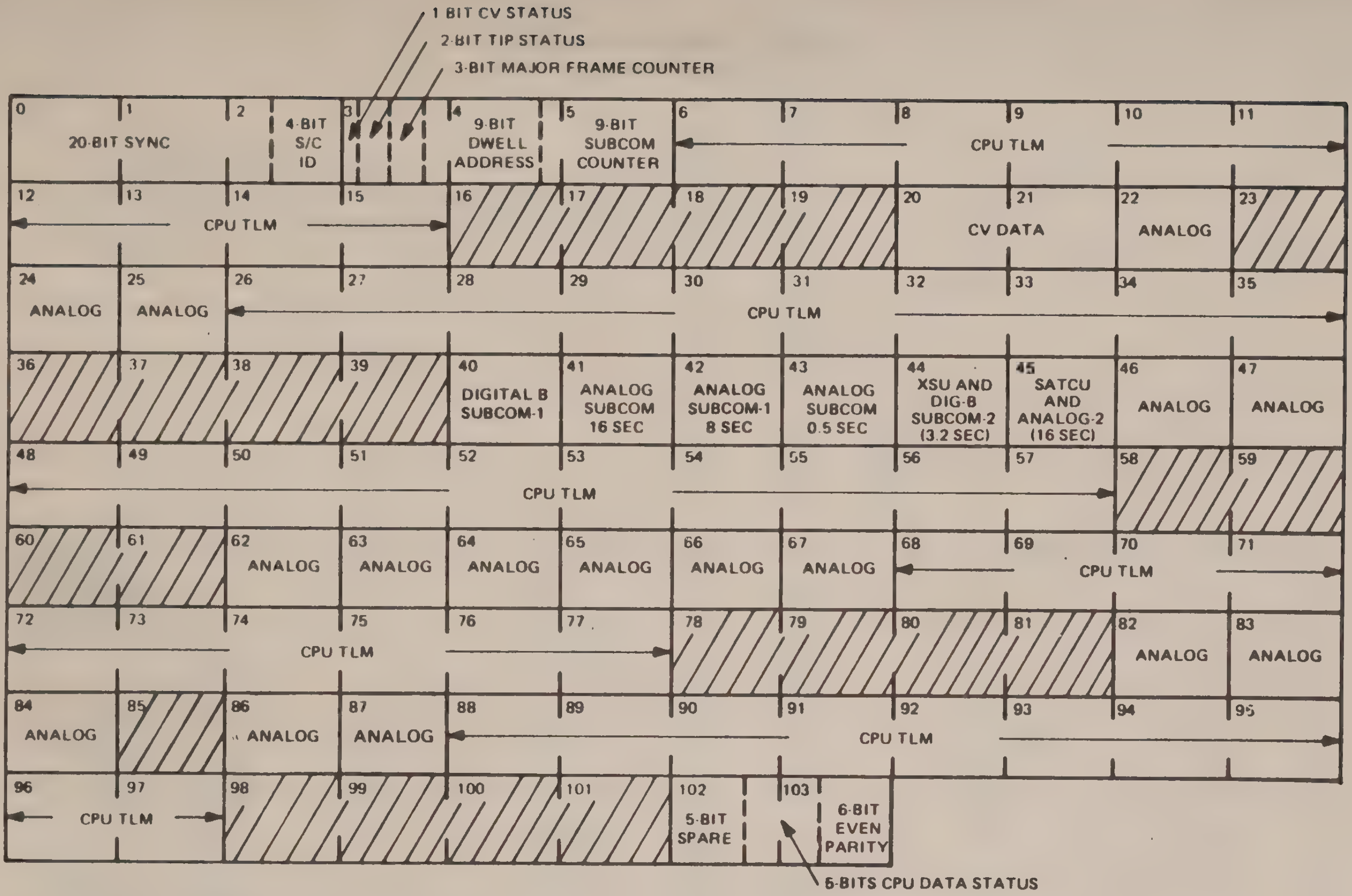
- TIP Status. The TIP generates a 2-bit status code during bits 2 and 3 of word 3 as follows:

Bit 2	Bit 3	Status
0	0	Orbital mode
1	0	CPU memory dump mode
0	1	Dwell mode
1	1	Boost mode

- Major Frame Counter. The TIP counts major frames. Bits 4 through 6 of word 2 contain the binary representation of the major frame count, with code 000 representing major frame 0 and code 111 representing major frame 7.

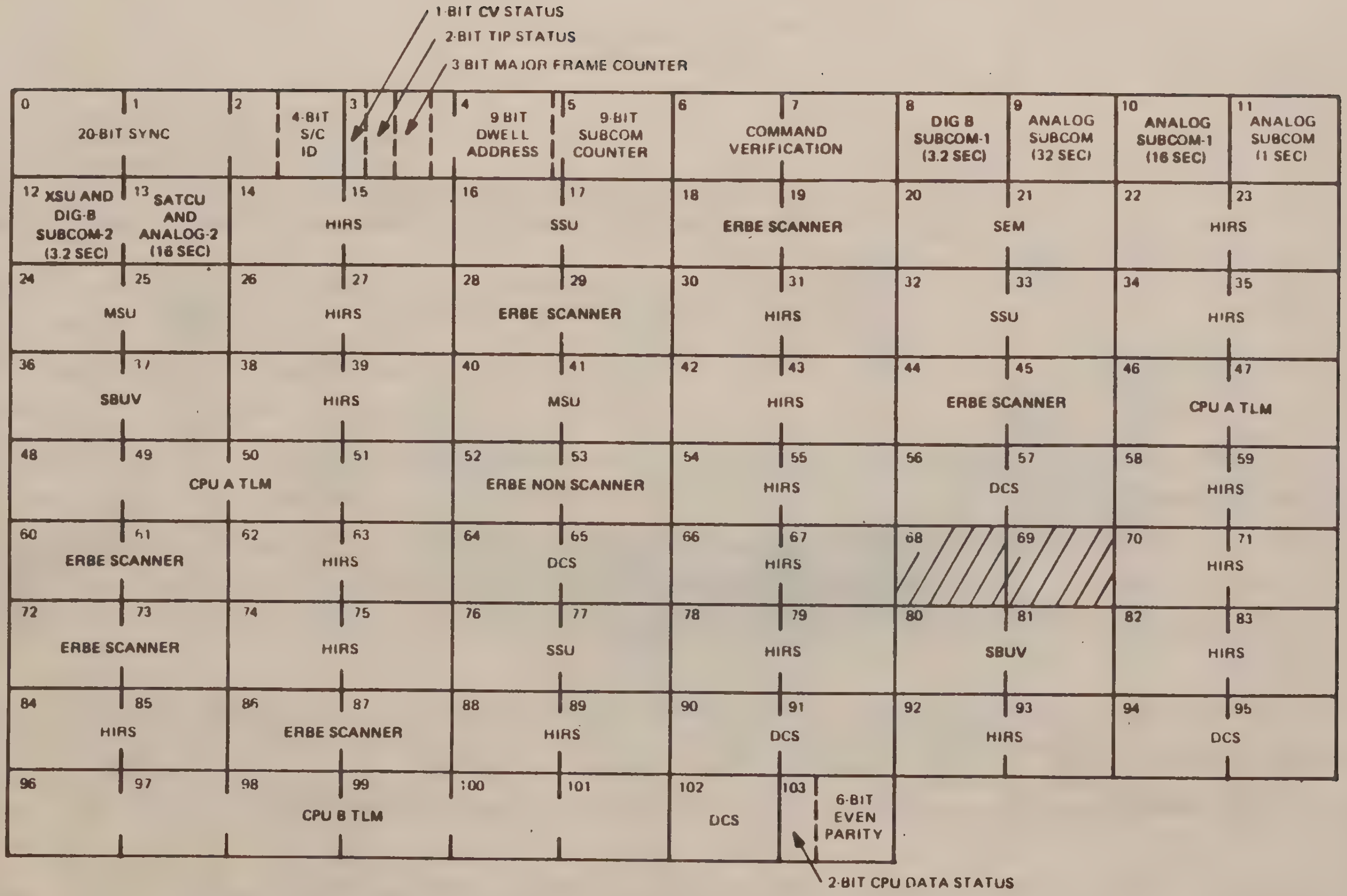
- Dwell Address. This is a 9-bit address specifying the analog dwell channel sampled on command in word 0 of the 0.5 analog subcom. Bit 8 of word 2, bits 7 and 8 of word 3, and bits 1 through 7 of word 4 contain the dwell channel address. Code 000000000^{B} represents analog channel 0_D, and Code 111111111_B represents channel 511_D.

- Minor Frame Counter (Subcom Counter). The minor frame counter contains a 9-bit binary representation of the minor frame number. Code 000000000_B represents minor


1 BIT CV STATUS
2-BIT TIP STATUS
3-BIT MAJOR FRAME COUNTER
0
1
20-BIT SYNC
2
4-BIT S/C ID
3
4
9-BIT DWELL ADDRESS
5
9-BIT SUBCOM COUNTER
6
7
8
9
CPU TLM
10
11
12
13
14
15
CPU TLM
16
17
18
19
20
21
CV DATA
22
ANALOG
23
24
ANALOG
25
ANALOG
26
27
28
29
30
31
CPU TLM
32
33
34
35
36
37
38
39
40
DIGITAL B SUBCOM-1
41
ANALOG SUBCOM 16 SEC
42
ANALOG SUBCOM-1 8 SEC
43
ANALOG SUBCOM 0.5 SEC
44
XSU AND DIG-B SUBCOM-2 (3.2 SEC)
45
SATCU AND ANALOG-2 (16 SEC)
46
ANALOG
47
ANALOG
48
49
50
51
52
53
CPU TLM
54
55
56
57
58
59
60
61
62
ANALOG
63
ANALOG
64
ANALOG
65
ANALOG
66
ANALOG
67
ANALOG
68
69
CPU TLM
70
71
72
73
74
75
CPU TLM
76
77
78
79
80
81
82
ANALOG
83
ANALOG
84
ANALOG
85
86
ANALOG
87
ANALOG
88
89
90
91
CPU TLM
92
93
94
95
96
97
CPU TLM
98
99
100
101
102
5-BIT SPARE
103
6-BIT EVEN PARITY
6-BITS CPU DATA STATUS

NOTES. 1) NUMBER IN UPPER LEFT-HAND CORNER INDICATES MINOR FRAME WORD NUMBER.
2) TIME CODE DATA APPEARS DURING MINOR FRAME "0" WORD LOCATIONS 40 THROUGH 44.
3) ///// INDICATES SPARE WORD LOCATIONS, AND CONTAINS CODE 01010101.
4) MINOR FRAME PERIOD 0.05 SECOND
MAJOR FRAME PERIOD – 16 SECONDS
OUTPUT DATA RATE – 16.64 kbps

Figure III-18
TIP Boost Mode Format



0 20-BIT SYNC	1	2 4-BIT S/C ID	3	4 9 BIT DWELL ADDRESS	5 9-BIT SUBCOM COUNTER	6 COMMAND VERIFICATION	7	8 DIG B SUBCOM-1 (3.2 SEC)	9 ANALOG SUBCOM (32 SEC)	10 ANALOG SUBCOM-1 (16 SEC)	11 ANALOG SUBCOM (1 SEC)
12 XSU AND DIG-B SUBCOM-2 (3.2 SEC)	13 SATCU AND ANALOG-2 (16 SEC)	14 HIRS	15	16 SSU	17	18 ERBE SCANNER	19	20 SEM	21	22 HIRS	23
24 MSU	25	26 HIRS	27	28 ERBE SCANNER	29	30 HIRS	31	32 SSU	33	34 HIRS	35
36 SBUV	37	38 HIRS	39	40 MSU	41	42 HIRS	43	44 ERBE SCANNER	45	46 CPU A TLM	47
48 CPU A TLM	49	50	51	52 ERBE NON SCANNER	53	54 HIRS	55	56 DCS	57	58 HIRS	59
60 ERBE SCANNER	61	62 HIRS	63	64 DCS	65	66 HIRS	67	68 ▨	69 ▨	70 HIRS	71
72 ERBE SCANNER	73	74 HIRS	75	76 SSU	77	78 HIRS	79	80 SBUV	81	82 HIRS	83
84 HIRS	85	86 ERBE SCANNER	87	88 HIRS	89	90 DCS	91	92 HIRS	93	94 DCS	95
96 CPU B TLM	97	98	99	100	101	102 DCS	103 6-BIT EVEN PARITY				

NOTES
1) NUMBER IN UPPER LEFT-HAND CORNER INDICATES MINOR FRAME WORD NUMBER
2) TIME CODE DATA APPEARS DURING MINOR FRAME "0" WORD LOCATIONS 8 THROUGH 12
3) ///// INDICATES SPARE WORD LOCATIONS, AND CONTAINS CODE 01010101
4) MINOR FRAME PERIOD – 0.1 SECOND
MAJOR FRAME PERIOD – 32 SECONDS
OUTPUT DATA RATE – 8.32 kbps

Figure III-19
TIP Orbital Mode Format

frame 0_D, and code 10011111_B represents minor frame 319_D.

- CPU Telemetry. CPU Telemetry contains housekeeping telemetry produced by CPU software.

- CV Data. CV words present the last CV message received from the CIU. Each time a new CV message is loaded into these words, the fact is noted in the CV status bit.

- Time Code Data. Time code data tags the beginning of minor frame 0 to within +1 and -3 ms. The format is as follows:

9 Bits (Day Count)	0	1	0	1	27 Bits (ms of Day Count)
	(4-Bits Spare)				

The milliseconds-of-day counter resets and advances the day counter once every 24 hours. The day counter counts up to 512 days before resetting.

- Commutated Words. Six commutated words contain satellite digital and digitized analog telemetry data. The input information for these words is as follows:
  - 512 individual wires, each carrying a voltage level that the TIP digitizes, with all but one wire monitoring a single quantity each, and the remaining one monitoring 16 quantities via the Solar Array Telemetry Commutating Unit (SATCU).
  - 352 individual wires each carrying a "bilevel" voltage that the TIP interprets as logic "1" or "0" are used for mode status indications.
  - A digital-A interface with the XSU; used for XSU mode status indication.

- CPU Data Status. Bits 6 through 8 of word 102, and bits 1 and 2 of minor frame word 103, report on success or failure of the CPU data handshake by which CPU data are transferred to the TIP. A "0" denotes the transfer succeeded. A "1" denotes it was incomplete. The bit positions report on different parts of the transfer as follows:

Word Number	Bit Number	Report on Transfer in Word Locations
102	6	6 through 19
102	7	26 through 39
102	8	48 through 61
103	1	68 through 81
103	2	88 through 101

- Parity. Bits 3 through 8 of word 103 provide an even parity check on TIP data. The bits have the following interpretation:

Bit	Interpretation (Even Parity Check on Data Contained in Words)
3	2 through 18
4	19 through 35
5	36 through 52
6	53 through 69
7	70 through 86
8	87 through 102 including bits 1 through 7 of word 103

- Analog Telemetry Words. Sixteen word locations in each minor frame contain digitized analog housekeeping telemetry.

c. Operational Orbit Modes

Subsystem Operations. Routine operation of the DHS in operational orbit requires only the following mode changes:

- DTR record/playback management
- APT channel selection
- APT minute-marker adjustment
- TIP/MIRP time code correction
- TIP to orbit or CPU dump modes

The static mode status is:

- MIRP ON, hence APT data to both VTXs
- HRPT data to STX-1 or -3
- TIP data to both BTXs (not commandable)

DTR management meets the requirements for GAC and LAC playbacks to the CDA stations and TIP playbacks to Lannion. A typical playback time of 2-1/2 minute per stored orbit of GAC data, or per 10 minute stored span of LAC data, allows complete recovery of all the LAC and GAC data from multiple blind orbits no later than the second CDA pass afterward. To achieve this, the CDA stations can use parallel playback on

STX-2, either on STX-1 or -3. DTR management is normally accomplished by stored command. NOAA corrects the time of occurrence of the APT minute marker by stored command. Also, NOAA corrects TIP, and hence MIRP time, by stored command. Routine verification of loads of "perishable" tabular data to the CPUs requires the TIP to switch to the CPU dump mode. An example is the stored command table. After the verification, TIP switches back to the orbit mode. During dump mode, the space allocated to CPU data in the TIP format remains fixed, but the TIP/CIU "handshake" changes to route data from only one CPU (rather than from both) to the TIP. Having matching mode changes in the CIU, and in the flight software, results in all the CPU data allocation being used for a "mirror-back" of the most recent load. These mode changes are by real-time command.

Subsystem Formats. All the primary DHS formats used in operational orbit are defined here. The description omits several fallback and diagnostic formats by the MIRP.

TIP Orbit Mode Format. The TIP orbit mode format is shown in figure III-19, and its major parameters are defined in Table III-15. The following description refers to the illustration. The definitions previously given for the TIP boost mode format apply, except for the following:

- CPU Data Status. Bits 1 and 2 of minor frame word 103 report on the success or failure of the CPU data handshake by which CPU data are transferred to the TIP. Bit 1 reports on the first six CPU words in a frame, and bit 2 on the last. "0" means good transfer and "1" means incomplete transfer.

- Digital-A Words. Words marked SSU, HIRS/2, SEM, MSU, SBUV/2, and DCS contain digital-A data from those government-furnished instruments.

- Commutated Words. The period of all the subcoms are double the values in boost mode. Since each subcom name defines its period, the names are changed accordingly. The structures are unchanged.

TIP CPU Dump Format. All definitions for TIP orbit mode format apply, except for the CPU data. Here, all the "CPU Telemetry" words contain, instead, CPU dump data from a single CPU. The CPU is selected by command. In routine operations, this mode is used to verify correct loads of tables of perishable data in the CPU, such as the stored command table.

TIP Single-Point Dwell Format. This format is identical to the TIP orbit mode format with the exception of words 14 through 103, which are all dedicated to a single analog telemetry channel, selected by command. This mode is useful for troubleshooting a major satellite problem, but its use comes at the price of losing all the low-rate sensor data and all CPU housekeeping telemetry.

HRPT/LAC Formats. The HRPT/LAC format is shown in figure III-20, and its major parameters are defined in table III-10. The following descriptions refer to the illustration.

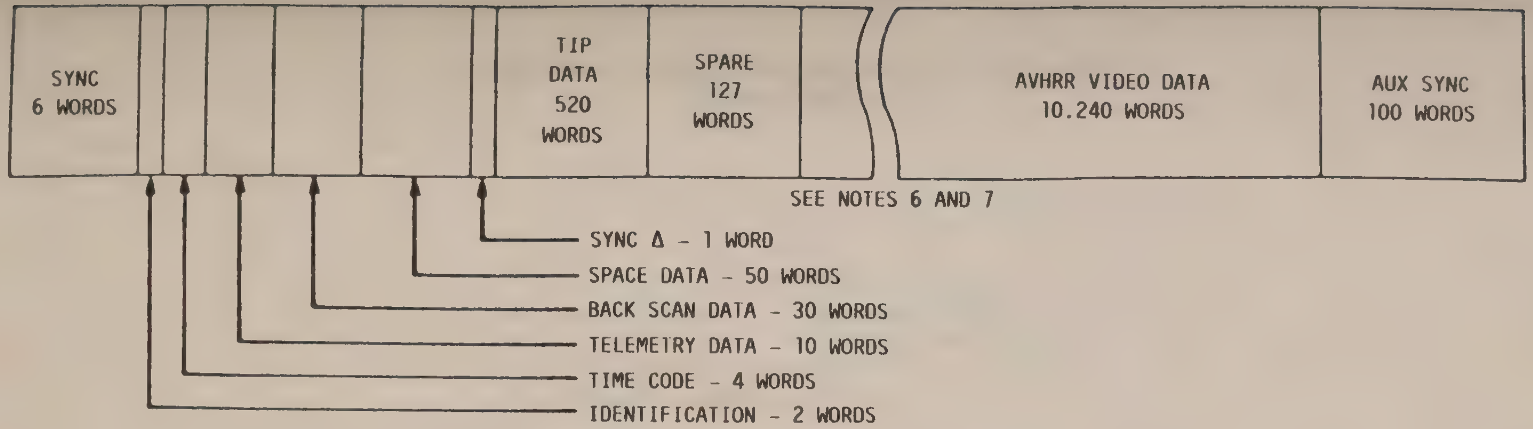
- Sync Words (words 1 through 6). The words contain a sync code obtained by using the first 60 bits of a 63-bit PN sequence, generated by a sixth-degree polynominal generator, as shown in figure III-21.

- Identification Words (words 7 and 8). Word 7 is coded as shown below. Word 8 is a spare.

Bit	Data	Definition
1	0	Internal Sync
	1	AVHRR Sync
2,3	00	GAC Frame
	01	HRPT/LAC Frame No. 1
	10	HRPT/LAC Frame No. 2
	11	HRPT/LAC Frame No. 3
4-7	X	Satellite Address
8	0	Frame Stable
	1	Frame Resync Occurred
9	1	Input Data from AVHRR
	0	Input Data from PN Code
10	1	Spare - (Bit 10 = 1)

The time at bit 1 of word 1 is 1.13 ±0.5 ms later than the value given in the time code word. The time code is shown below.

Word	Bit	Data Content
9	1-9	Binary Day Count, Bit 1 is the MSB, Bit 9 is the LSB.
	10	Spare - Data 0.

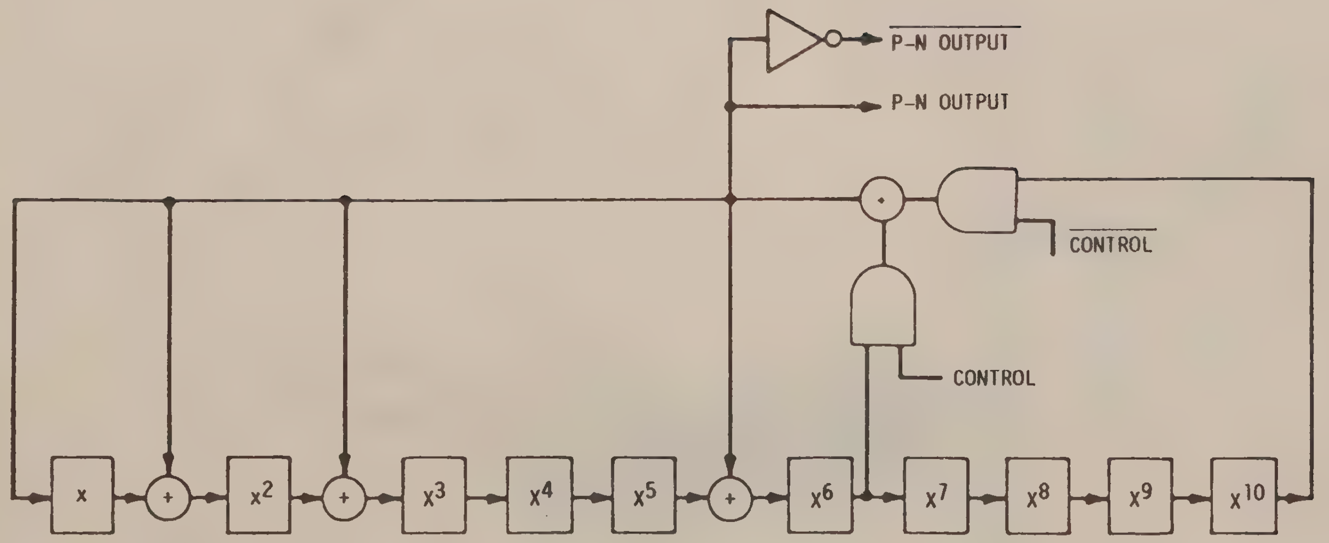

SYNC
6 WORDS
TIP
DATA
520
WORDS
SPARE
127
WORDS
AVHRR VIDEO DATA
10.240 WORDS
AUX SYNC
100 WORDS
SEE NOTES 6 AND 7
SYNC Δ - 1 WORD
SPACE DATA - 50 WORDS
BACK SCAN DATA - 30 WORDS
TELEMETRY DATA - 10 WORDS
TIME CODE - 4 WORDS
IDENTIFICATION - 2 WORDS

TELEMETRY WORD ALLOCATIONS		ID WORD BIT ALLOCATIONS		
		1ST ID WORD		2ND ID WORD
1-5	RAMP CALIBRATION	1	SYNC ID	(SPARE) CONTENTS UNDEFINED
6	CHANNEL 3 TARGET TEMP (5 POINT SUBCOM)	2-3	FRAME ID	
7	CHANNEL 4 TARGET TEMP (5 POINT SUBCOM)	4-7	SATELLITE ADDRESS	
8	CHANNEL 5 TARGET TEMP (5 POINT SUBCOM)	8	RESYNC MARKER	
9	CHANNEL 3 PATCH TEMP	9	INPUT FROM AVHRR/PH CODE	
10	SPARE	10	DATA 1	

NOTES:

(1) MINOR FRAME LENGTH - 11,090 WORDS
(2) THREE MINOR FRAMES PER MAJOR FRAME
(3) MINOR FRAME RATE - 6 FRAMES/SECOND
(4) WORD LENGTH - 10 BITS/WORD
(5) WHERE BIT CONTENTS OF LAC WORDS ARE SPECIFIED (AS IN NOTE 7). THE SPECIFICATION APPLIES PRIOR TO DATA RANDOMIZING
(6) HRPT OUTPUT - ALL SPARES ARE 10TH DEGREE P-N CODE (BAR)
(7) LAC OUTPUT - ALL SPARES ARE DATA "0"

Figure III-20
HRPT/LAC Frame Format


P-N OUTPUT
P-N OUTPUT
CONTROL
CONTROL
x
x^2
x^3
x^4
x^5
x^6
x^7
x^8
x^9
x^{10}

NOTES

(1) X1 THROUGH X10 ARE FLIP-FLOPS

(2) ⊕ ARE EXCLUSIVE OR GATES

(3) $X^6 + X^5 + X^2 X + 1$ IS GENERATED WHEN "CONTROL" 1

(4) $X^{10} + X^5 + X^2 X + 1$ IS GENERATED WHEN "CONTROL" 0

(5) STARTING POINT IS THE ALL "1" STATE

Figure III-21
Sixth and Tenth Degree Polynomial Generators

Word	Bit	Data Content
10	1-3	Spare - Data 1,0,1.
	4-10	Part of Binary ms of Day Count, Bit 4 is the MSB.
11, 12	1-10	Remainder of Binary ms of Day Count. Bit 10 of Word 12 is the LSB.

- Telemetry Data (words 13 through 22). These words contain the first AVHRR data in the format. All such data are obtained by a handshake in which the MIRP requests one sample by a "sample pulse," and the AVHRR responds with digitized data from each of five channels in sequence. The schedule of requests, shown in table III-20, uses as a starting point a "line sync" pulse that the AVHRR provides once each turn of its mirror. Here, the numerical designation of channel is in the sequence received, which is different from the channel numbers assigned by the AVHRR vendor.

The following list of sources for words 13 through 22 refers to the samples defined by table III-14:

Telemetry Words	Telemetry Data Allocations
13-17	Ramp Calibration - 1 per AVHRR channel
18	Channel 3 target temperature (5-point subcom)
19	Channel 4 target temperature (5-point subcom)
20	Channel 5 target temperature (5-point subcom)
21	Channel 3 patch temperature Bits 1 through 9 = Data 0
22	Spare
	Bit 10 = Data 1

Table III-20
MIRP Data Sample Times

Data	Sample Pulse Time*		Number of Sample Pulses Generated
	First Pulse	Last Pulse	
Space Data	101	110	10
Ramp Calibration	150	150	1
Earth Data	344	2391	2048
Target Temperature	2627	2627	1
Patch Temperature	2636	2636	1
Back Scan	4715	4724	10

* Sample pulse time in periods of 39,936 Hz following AVHRR line sync. The AVHRR outputs one sample from each channel (five in all) in response to each pulse.

- Back Scan Data (words 23 through 52). Data for these word positions are obtained from channels 3, 4, and 5 during the times given in table III-20. The order of data within the format is channels 3, 4, 5; channels 3, 4, 5; etc.

- Space Data (words 53 through 102). Data for these words are obtained from the AVHRR during the times in table III-20.

- Sync Delta (word 103). Provides a differential time measurement of the AVHRR line sync position relative to the position predicted by the internal MIRP line sync reference, coded as shown below:

Bit	Data	Definition
1	0	AVHRR sync is early
	1	AVHRR sync is late
2-10	X	9-bit binary count of 0.9984 MHz periods. Bit 2 is the MSB and bit 10 is the LSB.

- TIP Data (words 104 through 623). Words 104 through 623 consist of five frames (104 words per frame) of TIP data in the same sequence as output by TIP. Word 104 contains the first words of the first TIP minor frame. The first eight bits (bits 1 through 8) of each word are the same as received from the TIP. MIRP adds two parity check bits (bits 9 and 10) to each TIP word using the following algorithm:

  - Bit 9 is an even parity check on bits 1 through 8.

  - Bit 10 is bit 1 (complement of bit 1).

  - TIP data are identically repeated in three successive HRPT/LAC minor frames.

- Spare Words (words 624 through 750). These words are spares. In the HRPT format, these contain the inverted 1,023-bit sequence generated by continuous cycling of the 10th degree polynominal generator of figure III-21. The generator starts from the all "1" state at the beginning of word 7. For the LAC output, these 127 spare word positions contain data "0" (prior to randomization described below).

- Earth Data (words 751 through 10,990). These words are from the Earth-view portion of each AVHRR scan line as given in table III-20. The order of the output data within the format is channels 1, 2, 3, 4, 5; channels 1, 2, 3, 4, 5; etc.

- Auxiliary Sync (words 10,991 through 11,090). The code consists of the first 1,000 bits of a 1,023-bit PN sequence generated by a 10th degree polynomial generator as shown in figure III-21.

- LAC Data Randomization. The LAC data output is randomized. The randomization is performed as shown in figure III-22. Beginning at word 7 and continuing through word 10,990, the LAC data are exclusively OR'ed with the complemented output of the 10th degree PN generator in figure III-21.

  The PN generator is initialized to the all "1" state at the beginning of word 7 in each output frame.

MIRP GAC Format. The GAC format is shown in figure III-23, and its major parameters are defined in table III-17. The following descriptions refer to the illustration.

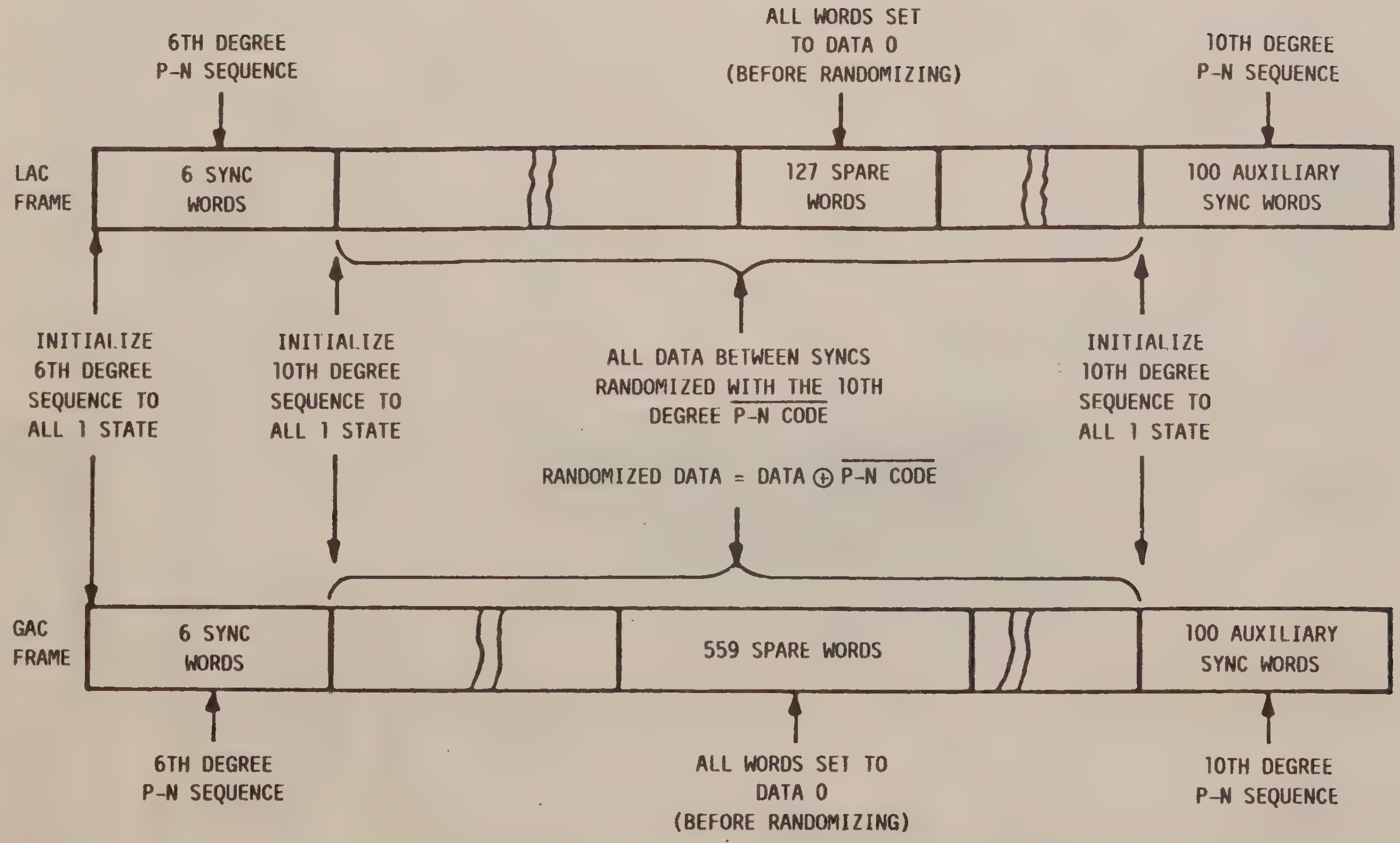
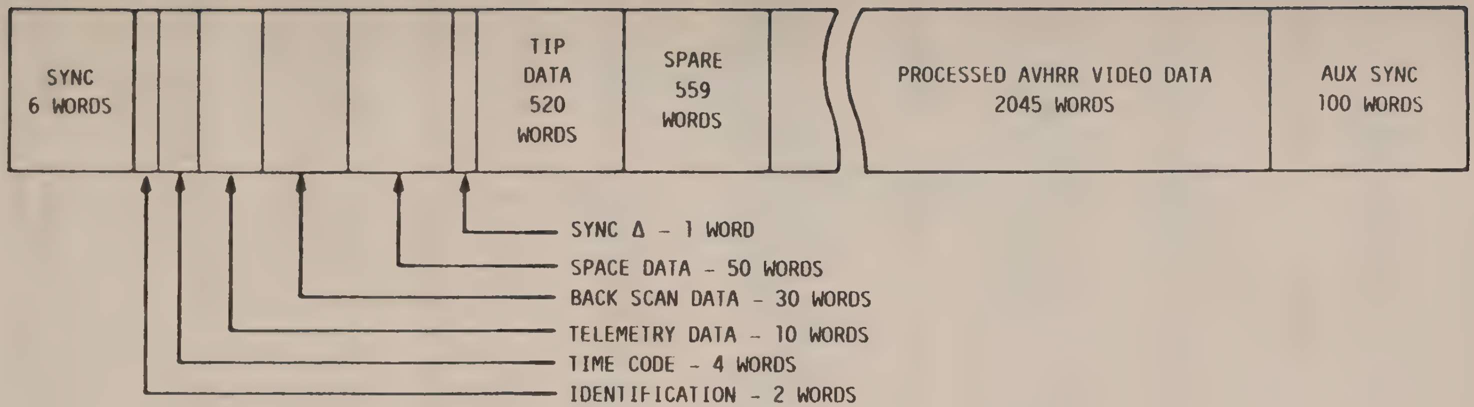

6TH DEGREE P-N SEQUENCE
ALL WORDS SET TO DATA 0 (BEFORE RANDOMIZING)
10TH DEGREE P-N SEQUENCE
LAC FRAME
6 SYNC WORDS
127 SPARE WORDS
100 AUXILIARY SYNC WORDS
INITIALIZE 6TH DEGREE SEQUENCE TO ALL 1 STATE
INITIALIZE 10TH DEGREE SEQUENCE TO ALL 1 STATE
ALL DATA BETWEEN SYNCS RANDOMIZED WITH THE 10TH DEGREE $\overline{\text{P-N CODE}}$
RANDOMIZED DATA = DATA $\oplus$ $\overline{\text{P-N CODE}}$
INITIALIZE 10TH DEGREE SEQUENCE TO ALL 1 STATE
GAC FRAME
6 SYNC WORDS
559 SPARE WORDS
100 AUXILIARY SYNC WORDS
6TH DEGREE P-N SEQUENCE
ALL WORDS SET TO DATA 0 (BEFORE RANDOMIZING)
10TH DEGREE P-N SEQUENCE

Figure III-22
Method of Randomization for LAC/GAC Data


SYNC
6 WORDS
TIP
DATA
520
WORDS
SPARE
559
WORDS
PROCESSED AVHRR VIDEO DATA
2045 WORDS
AUX SYNC
100 WORDS
SYNC Δ – 1 WORD
SPACE DATA – 50 WORDS
BACK SCAN DATA – 30 WORDS
TELEMETRY DATA – 10 WORDS
TIME CODE – 4 WORDS
IDENTIFICATION – 2 WORDS

NOTES

(1) FRAME LENGTH – 3327 WORDS
(2) FRAME RATE – 2 FRAMES/SECOND
(3) WORD LENGTH – 10 BITS
(4) SPARE WORDS ARE DATA "O"
(5) WHERE BIT CONTENTS OF WORDS ARE SPECIFIED (AS IN NOTE 4) THE SPECIFICATION APPLIES PRIOR TO DATA RANDOMIZING

TELEMETRY WORD ALLOCATIONS	ID WORD BIT ALLOCATIONS	
	1ST ID WORD	2ND ID WORD
1-5 RAMP CALIBRATION 6 CHANNEL 3 TARGET TEMP (5 POINT SUBCOM) 7 CHANNEL 4 TARGET TEMP (5 POINT SUBCOM) 8 CHANNEL 5 TARGET TEMP (5 POINT SUBCOM) 9 CHANNEL 3 PATCH TEMP 10 SPARE (UNDEFINED)	1 SYNC ID 2-3 FRAME ID 4-7 SATELLITE ADDRESS 8 RESYNC MARKER 9 INPUT FROM AVHRR PN CODE 10 DATA 1	1-10 ALL DATA UNDEFINED

Figure III-23
GAC Frame Format

The contents of the format are for HRPT/LAC as described in the preceding section, except as noted below:

- TIP Data. In the GAC format, new TIP data appear each frame, rather than every third frame as in HRPT/GAC.

- Spare Words (words 624 through 1,182). These words contain data "0's."

- Processed Earth Data (words 1,183 through 3,227). Data in these words are derived from the Earth-view portion of each AVHRR scan line, in accordance with the following algorithm:

  - Select only every third AVHRR scan line for data processing. From the selected scan, obtain five contiguous AVHRR data samples (samples 1 through 5) for each of the five AVHRR channels.

  - Retain the data from the first four samples. Discard the data from the fifth sample.

  - Form five separate binary sums, S1 through S5; form S1 by adding together the channel 1 data from samples 1, 2, 3, and 4; form S2 by adding together the channel 2 data from samples 1, 2, 3, and 4, etc; and form the sums in 12-bit precision.

  - Divide each of the sums, S1 through S5, by four to obtain the "averaged" GAC data words, D1 through D5, respectively. Round the quotients to 10 bits.

  - Repeat these steps a total of 409 times to generate the required 2,045 GAC data words.

- GAC Data Randomization. GAC data are randomized using the same rules as LAC data.

MIRP APT Format. A frame of the MIRP APT format is shown in figure III-24, and its major parameters are defined in table III-18. One video line from the frame is shown in figure III-25.

- APT Signal Analog Characteristics. The APT signal has the following analog characteristics:

  - Carrier Frequency - 2.4 kHz

  - Modulation Operating Range - Constant maximum numerical input (=255) to the digital-to-analog (D/A)

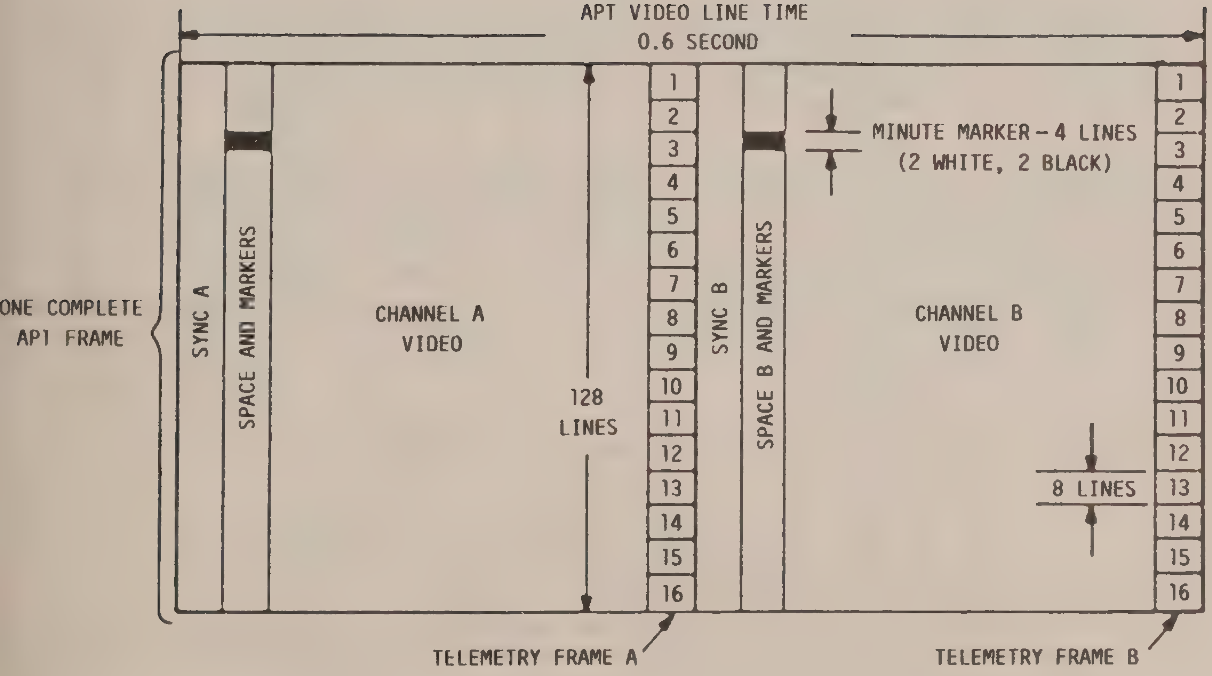
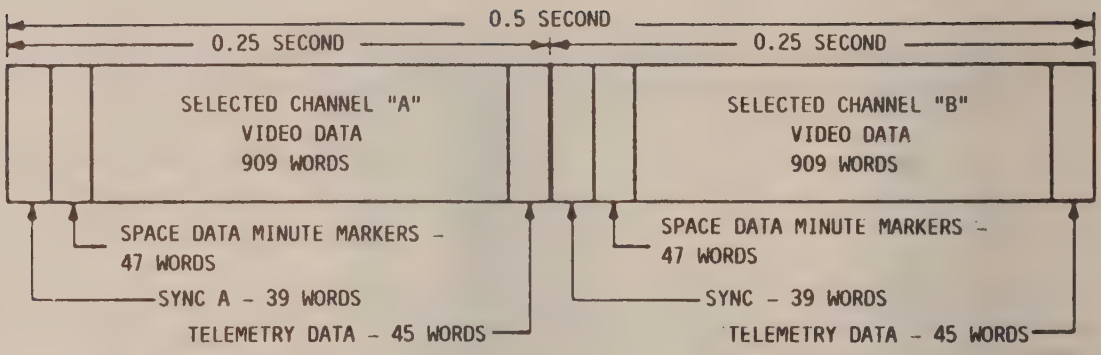

APT VIDEO LINE TIME
0.6 SECOND
ONE COMPLETE
APT FRAME
SYNC A
SPACE AND MARKERS
CHANNEL A
VIDEO
128
LINES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
SYNC B
SPACE B AND MARKERS
MINUTE MARKER - 4 LINES
(2 WHITE, 2 BLACK)
CHANNEL B
VIDEO
8 LINES
TELEMETRY FRAME A
TELEMETRY FRAME B

Figure III-24
APT Frame Format


0.5 SECOND
0.25 SECOND
0.25 SECOND
SELECTED CHANNEL "A" VIDEO DATA 909 WORDS
SELECTED CHANNEL "B" VIDEO DATA 909 WORDS
SPACE DATA MINUTE MARKERS - 47 WORDS
SYNC A - 39 WORDS
TELEMETRY DATA - 45 WORDS
SPACE DATA MINUTE MARKERS - 47 WORDS
SYNC - 39 WORDS
TELEMETRY DATA - 45 WORDS

NOTES
(1) EQUIVALENT OUTPUT DIGITAL DATA RATE IS 4160 WORDS/SECONDS
(2) VIDEO LINE RATE - 2 LINES/SECOND
(3) APT FRAME SIZE - 128 LINES
(4) ANY TWO OF THE FIVE AVHRR CHANNELS MAY BE SELECTED FOR USE
(5) SYNC A IS A 1040 H_Z SQUARE WAVE - 7 CYCLES
(6) SYNC B IS A 832 pps PULSE TRAIN - 7 PULSES
(7) Each of 16 TELEMETRY POINTS ARE REPEATED ON 8 SUCCESSIVE LINES
(8) MINUTE MARKERS ARE REPEATED ON 4 SUCCESSIVE LINES WITH 2 LINES BLACK AND 2 LINES WHITE

Figure III-25
APT Video Line Format (Prior to D/A Conversion)

- converter produces constant maximum subcarrier amplitude. Constant minimum numerical input (=0) to the D/A converter produces constant minimum subcarrier amplitude (0.07 +0.03).

- Linearity - Subcarrier amplitude is proportional to the numerical input to the D/A converter plus 2 percent of maximum subcarrier amplitude over the operating range, defined above.

- Filtering - The APT signal passes through a low-pass filter before it is amplitude-modulated, and another low-pass filter after amplitude modulation. The premodulation filter is a third order low-pass transitional Butterworth Thomson filter, with a 2400 Hz 3-dB bandwidth. The postmodulation filter is a three-pole Butterworth low-pass filter, with a 6000 Hz 3-dB bandwidth.

- APT Video Line Structure. Each line of APT output video data contains 2,080 analog video elements. Each element is present in the video line for a period of one APT word duration, as defined in table III-18. Each element (except sync A and sync B) is proportional to the result of a D/A conversion of the eight most significant bits of a 10-bit digital word. Each line is structured as shown in figure III-25, and contains the following video information:

  - Sync A
  - Space A with minute markers
  - Channel A video
  - Telemetry A (16-point subcom)
  - Sync B
  - Space B with minute markers
  - Channel B video
  - Telemetry B (16-point subcom)

- APT Sync Format. Every line of APT video data contains two sync intervals, designated as sync A and sync B. Sync A precedes the space data A interval and equals 39 APT words, nominally 9.375 ms in duration. It contains seven cycles of a square wave with a frequency of 1040 Hz.

  Sync B begins at the midpoint of each video line and precedes the space data B interval. It lasts for a period equal to 39 APT words (nominally 9.375 ms), and contains seven pulses of a train, with a frequency of

832 pps. Sync B pulses have a 3:2 symmetry ratio, as shown in figure III-26.

- APT Space Data and Minute Markers. Immediately following the sync A and sync B intervals, each APT video line contains space data that are periodically overwritten by a time reference marker occurring at a 1 min repetition rate. Each space data interval immediately precedes the channel video information and occupies 47 APT words, nominally 11.298 ms in duration. The space data in each interval are derived from the same AVHRR channel, whose data are presented in the following video interval. Minute marker data are inserted into the space data interval every minute, and override the existing space data. Minute markers are repeated on four consecutive video lines for every occurrence of the marker, and are composed of two lines of maximum modulation, and two lines of minimum modulation.

- Processing of APT Earth Data. The data contained in the two Earth data portions of the APT lines are each derived by processing a single channel of AVHRR input data. The processing of the data varies as a function of its position within the AVHRR scan line, and is done to accomplish bandwidth reduction and geometric correction. All processing is performed digitally. The data processing algorithm averages every third scan line of AVHRR data. The averaging process applies to a single AVHRR channel, and is divided into five regions, as shown in table III-21. The algorithm is as follows:

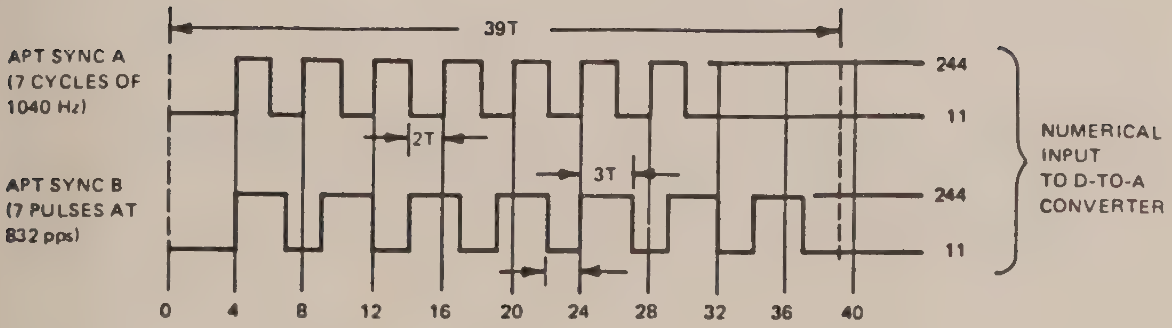
    - In region 1 (nominally $\pm 16.98^\circ$ on either side of nadir), average each contiguous group of four samples from the selected channel.

    - In region 2 (nominally -34.83° to -16.98° and $+16.98^\circ$ to $+34.83^\circ$), average each contiguous group of two samples, skip one sample and repeat.

    - In region 3 (nominally -43.81° to -34.83° and $+34.83^\circ$ to $+43.81^\circ$), average each contiguous group of two samples.

    - In region 4 (nominally -48.84° to -43.81° and $+43.81^\circ$ to $+48.84^\circ$), consider a contiguous group of three samples A, B, C. Derive two output values as follows:

    $$\frac{A+B}{2} \quad \text{and} \quad \frac{B+C}{2}$$


39T
APT SYNC A
(7 CYCLES OF
1040 Hz)
APT SYNC B
(7 PULSES AT
832 pps)
2T
3T
244
11
244
11
NUMERICAL
INPUT
TO D-TO-A
CONVERTER
0
4
8
12
16
20
24
28
32
36
40

NOTES. (1) $T = \frac{1}{4160}$ SECOND.

(2) SYNC A PRECEDES CHANNEL A DATA.

(3) SYNC B PRECEDES CHANNEL B DATA.

Figure III-26
APT Sync Details

Table III-21
APT Earth Data Processing Regions

APT Data Processing Region		Times of Data Sample Pulses (clock counts)(1)		Number of AVHRR Data Samples Collected Per Channel	Number of Processed APT Words Output to D/A Converter Per Selected Channel
Region Number	Before/ After Nominal Nadir(2)	First Pulse	Last Pulse		
5	Before	8,600	11,600	121	121
4	Before	11,625	13,925	93	62
3	Before	13,950	18,075	166	83
2	Before	18,100	26,325	330	110
1	Before	26,350	42,025	628	157
2	After	42,050	50,275	330	110
3	After	50,300	54,425	166	83
4	After	54,450	56,750	93	62
5	After	56,775	59,775	121	121

Notes: (1) "Clock Counts" are counts of the 0.9984 MHz clock after the leading edge of AVHRR line sync (or internal sync mode).

(2) Nominal nadir is at 34,200 counts.

Table III-22
APT Grey-Scale Parameters

Telemetry Point, Grey Scale Wedge	Subcarrier Amplitude - Fraction of "Operating Range" Used
1	31/255
2	63/255
3	95/255
4	127/255
5	159/255
6	191/255
7	223/255
8	1.0
9	0

- In region 5 (nominally -55.38° to -48.84° and +48.84° to +55.38°), use input samples unmodified.

Two successive AVHRR scan lines are used to obtain the Earth data for each APT line. One AVHRR scan line is used for channel A and the other scan line for channel B.

- APT Telemetry Data Frames. The MIRP provides telemetry data in two separate intervals within each APT video line. Each telemetry point is repeated in each of eight successive APT video lines. Each telemetry frame consists of 16 individual telemetry points as shown in figure III-27. The telemetry points are formatted as detailed below:

Telemetry Point	Format
1 to 8	Gray Scale Wedge No. 1 to No. 8
9	Zero Modulation Reference
10 to 13	Thermistor Temperatures
14	Patch Temperature
15	Back Scan
16	Channel ID Wedge

- Telemetry Points 1 Through 9. Each of the first nine telemetry points in the APT telemetry frame consists of an individual step from a gray scale internally generated in the MIRP. The corresponding subcarrier amplitude is a fixed value during each step as given in table III-22.

  One of the five scans will provide a sample containing all "0's" in the six most significant bits, and this sample is the temperature reference point. The samples in the four scans following the temperature reference point are infrared target temperature samples 1 through 4, in order.

- Patch Temperature. Telemetry point 14 indicates AVHRR patch temperature. Data for this point are obtained from channels 3, 4, or 5, selectable by command, when sampled during the patch temperature time specified in table III-20. Data for this point are the same in both APT telemetry frames, telemetry A and telemetry B.

- Back Scan. Telemetry point 15 contains back-scan data. The data for this point are obtained from a single sample

ONE COMPLETE TELEMETRY FRAME

WEDGE NO. 1 1	WEDGE NO. 2 2	WEDGE NO 3 3	WEDGE NO. 4 4	WEDGE NO. 5 5	WEDGE NO 6 6	WEDGE NO 7 7	WEDGE NO. 8 8
ZERO MODULATION REFERENCE 9	THERMISTOR TEMP NO 1 10	THERMISTOR TEMP NO. 2 11	THERMISTOR TEMP NO 3 12	THERMISTOR TEMP NO. 4 13	PATCH TEMP 14	BACK SCAN 15	CHANNEL ID WEDGE 16

NOTES (1) EACH TELEMETRY FRAME CONSISTS OF 16 POINTS.
(2) TELEMETRY FRAME RATE IS 1 FRAME PER 64 SECONDS.
(3) EACH TELEMETRY POINT IS REPEATED ON 8 SUCCESSIVE APT VIDEO LINES

Figure III-27
APT 16-Point Telemetry Frame

of video data during the back-scan interval defined in table III-20. Back-scan data in telemetry frame A are obtained from the same AVHRR channel used in the channel A portion of the APT video line. Back-scan data in telemetry frame B are obtained from the same AVHRR channel used in the channel B portion of the APT video line.

- Channel Identification Wedge. The 16th telemetry point is channel identification. This is done by inserting, in this telemetry point, subcarrier amplitude equal to one of the first five gray-scale steps. The channel number is the same as the number of the corresponding gray-scale step.

E. COMMAND AND CONTROL OVERVIEW

1. DMSP

a. Command and Control Overview. Earth-based C^2 and telemetry processing for the satellite are contained in the C^3 segment. Through its communications links, the C^3 segment provides all functions required to maintain the health and welfare of the DMSP satellites and provides communications media to recover the meteorological payload data acquired during the satellite's orbit. Although real-time primary sensor data are available to deployed tactical terminals worldwide, access to more comprehensive stored data is obtained only when the satellite is within the station circle of one of the C^3 segment's remote Command Readout Stations (CRS). The maximum access period is approximately 15 minutes of each orbit. During this time, the C^3 segment through a CRS must command the satellite in real time; uplink stored command inputs for satellite control when out of CRS station circle; analyze real-time health and welfare telemetry data; acquire orbital telemetry data for off-line trend analysis; provide communications for routing DMSP data to users; and recover stored data.

The C^3 segment makes use of several geographical ground station sites that operate as a whole to collect worldwide meteorological data from the DMSP satellites orbiting the Earth. See chapter II, section C for site descriptions.

b. Operational Control. The Satellite Operations Center (SOC) is under the command of Space Command's 1000th Satellite Operations Group (1000 SOG). As the primary command and control site, the SOC contains the personnel and systems necessary to conduct all mission planning, spacecraft commanding, data relay, and telemetry processing.

Mission Planning. AFGWC meteorologists working through Site 3 operators request specific data types (e.g., smooth or fine data) at specific Earth locations from the Space Command spacecraft controllers at Site 5.

Mission planning encompasses all tasks associated with scheduling and data generation for the ground system and satellite operating activities. The mission planning area acts as a single point of contact for the users. It synthesizes the user's scheduled data needs, accepts engineering requests for special satellite tests, and processes satellite status information to create the operational data files necessary to control the DMSP satellite system. The mission planning area also receives the stored and real-time data coverage requirements from user organizations via AFGWC. In addition, requirements and constraints are received from 1000 SOG Engineering working with the DMSP System Program Office (SPO). These requirements and operational constraints are then incorporated into the automated mission planning data generation and verification system (PLANS). PLANS produces the operational data files utilized by the Commanding System to control the DMSP satellite.

Spacecraft Commanding. The Spacecraft Commanding area provides the capability to transmit and verify commands and satellite memory loads, update spacecraft clocks, and monitor, in real time, selected telemetry parameters in support of contingency commanding. Uplinking of individual specific spacecraft commands is performed at a two command/second rate, while the uplink of memory load inputs for execution of commands outside of station circle is supported at an 80 command/second rate. To uplink a command or memory load, the Spacecraft Commanding area forwards the command or memory load words to the CRS for uplink to the satellite.

Data Relay. The two DMSP CRSs perform the direct uplink and downlink communications with the DMSP satellite. All nominal data communications with a DMSP satellite are conducted via a CRS or the Hawaii Tracking Stations (HTS) for data recovery. These sites receive, demodulate, record, reformat, multiplex, and transmit DMSP satellite data, via WESTAR, to processing equipment at the AFGWC and FNOC. The command channel from the SOC to the CRSs is a single time division multiplexed channel that contains a composite of command, control, and digital voice at a 230.4 kbps rate. The command data stream is converted at each CRS to a form (serial to ternary) usable by the DMSP satellite and is then uplinked to the spacecraft. Since operator intervention is not required at the CRSs, the data stream is piped through to the spacecraft (hence, the term "bent pipe" operation). Because the data stream is processed in the "bent pipe" configuration for both uplink and downlink, the data can be encrypted/decrypted at either end with no hardware impact at the CRS. The CRS functions primarily as a "bent pipe" uplink and downlink station for L-band frequency transmission to the satellite and S-band frequency reception.

The uplink functions of the CRS consist of receiving and reformatting command data from the SOC. The reformatted command is then modulated onto a carrier and amplified by the high power amplifier located at the antenna feed.

The downlink function receives, stores, and forwards all incoming S-band signals to AFGWC and FNOC. As the S-band signals are being received, a diode scanner connected to four S-band dipoles (two for azimuth and two for elevation) is switched at a 94 Hz rate. This provides antenna pointing error data (pseudomonopulse auto tracking) to the antenna positioning subsystem for continual tracking update to ensure accurate positioning during track.

Antenna positioning is also computer controlled as a backup. The S-band (2.2 to 2.3 GHz) received signal is translated within a down converter to 300 to 400 MHz, and is routed to three sync units to extract the real-time telemetry and stored meteorological data for storage and forwarding. All data received from the satellite are recorded on instrumentation tape recorders. This storage system allows for post-pass playback in the event of a communications outage. During the pass, the highest priority meteorological data stream is forwarded via WESTAR to AFGWC and FNOC. The alternate data stream is retransmitted post-pass from the tape recorders.

Meteorological and telemetry data are multiplexed with site status data and the digital voice channel into a single 3.072 mbps data stream at each CRS. Site status and digital voice are not contained in the Hawaii Tracking Station's 3.072 mbps data stream. The channels from these three sites are uplinked to WESTAR and relayed to AFGWC and FNOC. Although both AFGWC and FNOC receive all of the data contained on all three channels, only AFGWC has the proper interface to forward telemetry, status, and voice data to the SOC.

Telemetry Processing. Telemetry processing provides the capability to ingest, convert, store, and display satellite health and welfare telemetry data for use by an operator in readable form. Two different types of telemetry, real-time telemetry (acquired during station circle passage) and stored telemetry (recorded while outside of station circle), are received for processing. The telemetry data may be received either concurrent with, or independent of, the command activity.

Real-time telemetry processing provides engineering units conversion and display for the satellite data analysts. In support of these analysts, out-of-limits and dwell alphanumeric telemetry displays are provided by the system on color graphics terminals. Since real-time telemetry values can change very rapidly, a virtual playback capability is also provided to allow the data analyst to replay significant events. Replays allow slow-motion viewing of the real-time telemetry.

Once the satellite contact period is over, the stored telemetry (previously acquired during real time) and the real-time telemetry data are merged into the on-line revolution-by-revolution telemetry data base. This data base is then accessed for post-pass computer analysis of telemetry.

Summary. In the summary, the SOC mission planning, spacecraft commanding, data relay, and telemetry processing are implemented in a multiprocessor network that interfaces with custom hardware and commercial communication equipment. The system is operated by five crews, eight people per crew, 24 hours per day. During each pass the crews coordinate the activities associated with command transmission, verification of command receipt, and monitoring overall satellite health. Figure III-28 provides an overview of DMSP commanding.

c. Payload Operations. The sensor payload of the current DMSP spacecraft (Block 5D-2) is composed primarily of the OLS, along with several mission-specific sensors.

The OLS data management unit has a capability for acquiring, processing, recording, and outputting data from up to 12 mission sensors. Mission sensors are scheduled in varying combinations for the Block 5D-2 spacecraft. Data coverage requirements for the OLS are provided by AFGWC to the 1000 SOG mission planners, who convert the requirements to spacecraft commands. Mission sensor commands are provided to the 1000 SOG by the sensor customers. See section B on page III-56 for payload details.

d. Communications. The communications area provides all data and voice communications for the system. Table II-3 shows the communications linking the SOC to all sites.

Data. The primary link from the SOC to the CRSs and the HTS is via WESTAR. Command and telemetry data are interfaced over this link, and then via the RF link to and from the DMSP satellite. The user interface from the DMSP satellites to FNOC and AFGWC is also via WESTAR.

Digital Voice Communications. Voice communications between the SOC and the two CRSs are provided over the satellite links. The voice signals from the normal intercom at the SOC

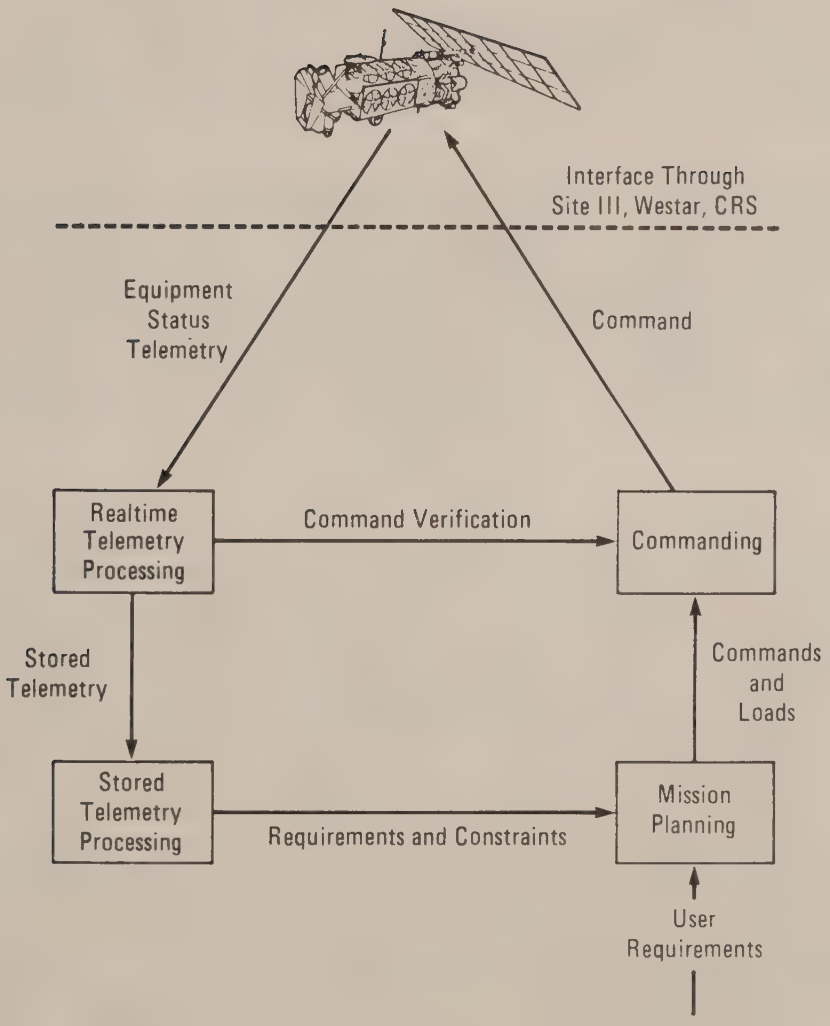

Interface Through
Site III, Westar, CRS
Equipment Status Telemetry
Command
Realtime Telemetry Processing
Command Verification
Commanding
Stored Telemetry
Commands and Loads
Stored Telemetry Processing
Requirements and Constraints
Mission Planning
User Requirements

Figure III-28
DMSP Satellite Operations Group Overview

are converted into a 14.4 kbps digital signal by a continuously variable slope detector (CVSD) voice processor. The digital signal is incorporated into the 230.4 kbps data stream for transfer to the CRSs. At the CRSs, the 14.4 kbps CVSD digital voice data stream is recovered and reconstructed to an analog output, which is routed to an intercom. Voice signals from the intercom at the CRS are digitized in a similar fashion and incorporated into the 3.072 mbps satellite data stream, which is transferred back through Site 3. At the SOC, a demultiplexer recovers the 14.4 kbps digital data stream. The digital voice is again converted into an analog signal and routed to an intercom.

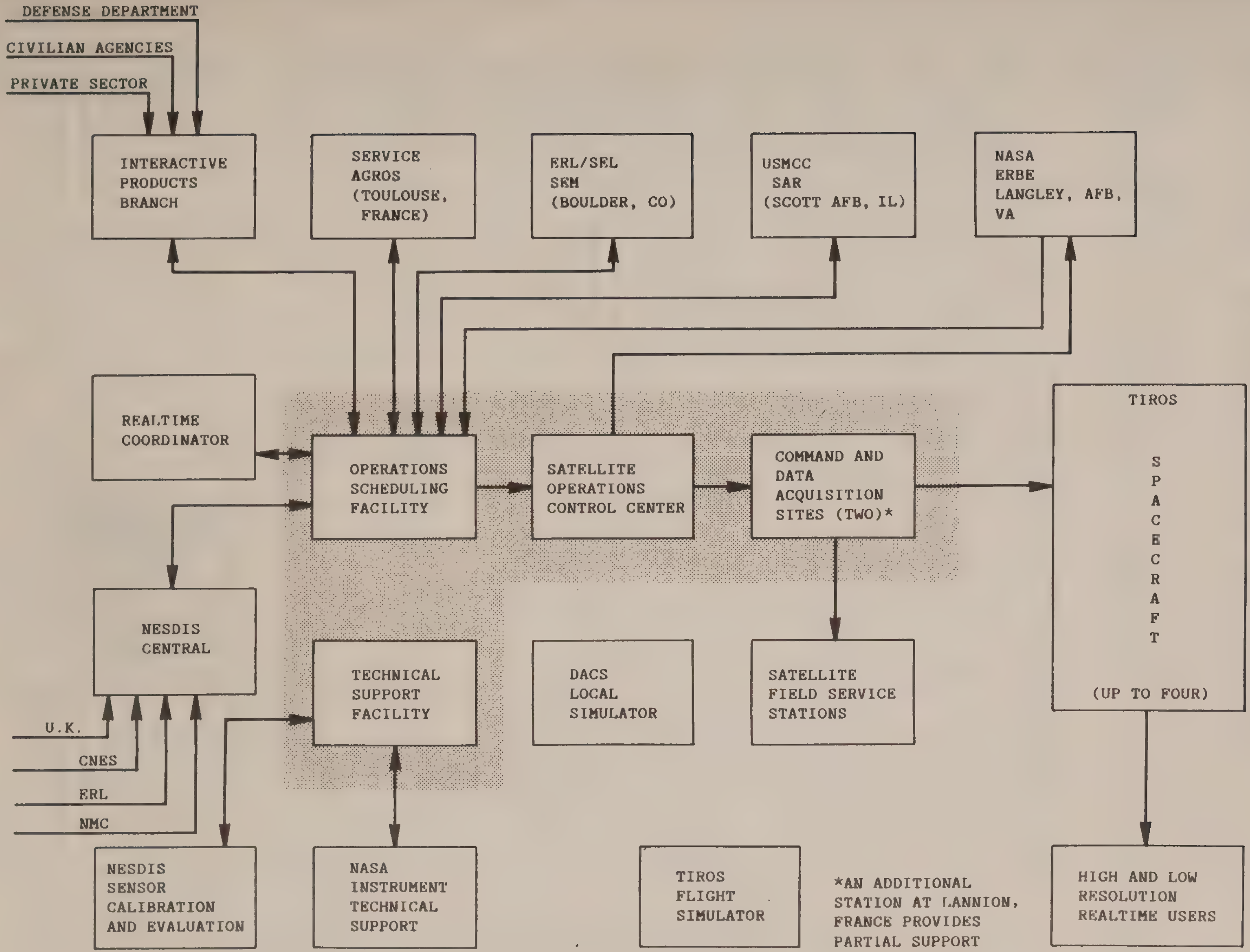
Terrestrial Lines. The use of terrestrial lines within the DMSP Communications Network is reserved for alternative voice communications between operators, and for backup command and telemetry data communications to and from the CRSs and the AFSCF. Meteorological data cannot be sent via terrestrial lines. All lines are C2/D1 conditioned for data transmission. The lines designated alternate voice/data have special switching equipment to remove the conditioning during voice transmission.

2. POES

a. Command and Control Overview. The main elements of the POES Command and Control System (CCS) are shown in figure III-29 within the hatched-in area. Proceeding from the spacecraft interface, these are (1) Command and Data Acquisition stations located at Wallops, Virginia; Fairbanks, Alaska; and Lannion, France; (2) the Satellite Operations Control Center, SOCC; (3) the Operations Scheduling Facility; and (4) the Spacecraft Technical Support Facility. The last three are located in Suitland, Maryland.

Used here, Sensor Command and Control means the management of POES system spacecraft payloads to realize mission objectives, which consist of operation for the maximum period of time in data-returning modes in accordance with defined acquisition schedules. Functionally, this breaks down to scheduling the POES system (spacecraft, Command and Data Acquisition stations, communications, and ingest systems), managing spacecraft housekeeping, and operating the command and control system for housekeeping and data acquisition.

Central to an understanding of the command and control structure is an understanding of two items with respect to each payload: (1) whether the data are applied centrally at NESDIS or remotely, and (2) whether the payload is controlled by NESDIS or externally. Of the present payload complement, the HIRS, MSU, SSU, and AVHRR are processed both centrally and remotely, and are controlled by NESDIS. The SAR, ERBE, DCS,


DEFENSE DEPARTMENT
CIVILIAN AGENCIES
PRIVATE SECTOR
INTERACTIVE PRODUCTS BRANCH
SERVICE AGROS (TOULOUSE, FRANCE)
ERL/SEL SEM (BOULDER, CO)
USMCC SAR (SCOTT AFB, IL)
NASA ERBE LANGLEY, AFB, VA
REALTIME COORDINATOR
OPERATIONS SCHEDULING FACILITY
SATELLITE OPERATIONS CONTROL CENTER
COMMAND AND DATA ACQUISITION SITES (TWO)*
TIROS SPACECRAFT (UP TO FOUR)
NESDIS CENTRAL
U.K.
CNES
ERL
NMC
TECHNICAL SUPPORT FACILITY
DACS LOCAL SIMULATOR
SATELLITE FIELD SERVICE STATIONS
NESDIS SENSOR CALIBRATION AND EVALUATION
NASA INSTRUMENT TECHNICAL SUPPORT
TIROS FLIGHT SIMULATOR
HIGH AND LOW RESOLUTION REALTIME USERS

*AN ADDITIONAL STATION AT LANNION, FRANCE PROVIDES PARTIAL SUPPORT

Figure III-29
Functional POES Payload Command and Control System

and SEM are used remotely and controlled by agencies other than NESDIS. The SBUV is unique, being controlled by NESDIS and only processed centrally.

The remainder of this section describes control element tasks, and interfaces and illustrates typical payload-related operations.

b. Control Elements and System Interfaces

System Scheduling. The Operations Scheduling Facility is staffed by a manager and three physical science technicians. The facility provides advanced planning for the spacecraft remote recording and communications subsystems. Included in advanced planning is managing acquisition conflicts and sensor data priorities. Advanced scheduling involves lead times of 17 days for global data and 24 days for high-resolution data. This means routine global data requirements need to be defined by users 17 days in advance. High-resolution data require a 24-day lead time. The scheduling system is flexible enough to accommodate short-term changes in anywhere from 8 to 48 hours, depending on the complexity of the change, and station acquisition pattern of the spacecraft involved. While long lead schedules are done on large NOAA NAS 9040 mainframes, day-to-day schedules are generated with 4-day lead times, on minicomputers. These schedules control the spacecrafts onboard computers, operations control center, and command and data acquisition computers, as well as front-end equipment, for up to 36 hours. Scheduling personnel define priorities and coordinate with the main interfaces shown in figure III-29. Generally, these are central, real-time, and high-resolution users, and spacecraft engineering and operational support personnel.

The data handling and communications subsystems of the spacecraft consist of a redundant housekeeping and low rate instrument multiplexer, the TIP, a nonredundant TIP and AVHRR multiplexer and data formatter, the MIRP, 10 digital tape recorders (DTRS), 3 S-band transmitters at 1698, 1702.5, and 1707 MHz, 4 VHF transmitters at 137.5, 137.62, 136.77, and 137.77 MHz, and a redundant L-band transmitter at 1544.5 MHz.

In normal scheduling, an L-band system is on continuously to transpond search and rescue data to local user terminals. Two of the four VHF transmitters operate continuously, one providing medium-resolution APT, the other providing real-time TOVS data, DSB, and housekeeping data required for command and control. One S-band system is scheduled for continuous transmission of HRPT data derived from the AVHRR. The number and frequencies of VHF and S-band systems allow the scheduling facility to manage radio frequency interference periods. These periods have 50 percent duty cycles, and have durations of 4.5 days for satellites in complementary node orbits, and 30 days for similar node orbits.

The remaining two S-band systems are used in conjunction with the digital recorders to allow programming, recording, playback, and acquisition of remotely derived data. In normal operation, three data sets are developed.

- A GAC data set of medium-resolution AVHRR, TOVS, SBUV, ERBE, SEM, DCS, and SAR data. The set requires 14 to 16 recordings daily, each of about 110 minutes.
- A selected LAC data set of up to one-tenth of an orbit of high-resolution AVHRR data. This snapshot data is multiuser orientated, and typically requires 15 to 20 recordings daily, each not exceeding about 11 minutes.
- A selected data set to two complete orbits of TOVS data, acquired daily at Lannion for Western Pacific and Eastern Atlantic NMC and WMO sounder requirements.

Spacecraft Subsystem Management. Spacecraft technical support is provided by an on-site contractor, who provides a manager and five engineers. This group is concerned with instrument performance evaluation, development of housekeeping and monitoring procedures for use by the control facility, and development of command management plans, which serve as working interface agreements between satellite operations and those agencies that manage their own instrument systems, such as Argos and SAR. As a consequence of each task, technical support provides routine spacecraft report histories, anomaly configuration control, ground system command and control data bases, and launch and mission critical augmentation of Control Center personnel. This group interfaces with operations scheduling for definition of housekeeping, and with NASA instrument technical officers, users, and NESDIS sensor evaluation analysts.

Part of payload management involves defining and preparing to cope with reasonably forseeable satellite problems that impact operations or satellite safety. To this end, contingencies are developed and placed within the POES command and control procedures. Some contingencies are active in the sense that actions have been taken to deal with a possible problem. For example, to deal with the possibility of an AVHRR failure on NOAA 9, the NOAA 7 spacecraft, which has severe power system problems, was unloaded, except for its AVHRR. In addition, special software was installed to limit excess power dissipated in shunts, by modulating the solar array azimuth angle. These actions maximized the prospect of having a usable afternoon AVHRR to back up NOAA 9. Another example of an active contingency concerns the failed NOAA 8 spacecraft. The

Command and Data Acquisition stations were equipped with software containing the code necessary to Earth-acquire the spacecraft, without the use of onboard gaseous nitrogen. Technical support personnel knew the necessary procedures to dampen spacecraft motion, magnetically reorient the spacecraft to the sun, and magnetically reduce momentum to within normal spacecraft control capabilities. When the failed satellite oscillator stabilized, the POES command and control system recovered the spacecraft.

Passive contingencies measures are in place to power down, or up, a spacecraft on an emergency basis, command a spacecraft to a known and benign "safe state," and support emergency commands initiated by Argos or SAR personnel.

Operational Control. The Satellite Operations Control Center (SOCC) is staffed around the clock by 4 1/2 crews of seven persons (physical science technicians, engineering technicians, and physical scientists). The group performs real-time instrument health and safety housekeeping; on-line management of system data flow; verification of instrument-related schedules, both real time and stored; execution of command programming; implementation of special procedures; and configuration and operation of command and control hardware.

The SOCC hardware consists of three Data General System 230 computers and a System 200 computer. Each S230 has 256K of random access memory, and 192 Mb of secondary memory. The S230s function as the heart of the POES Command and Control System, performing command and telemetry operations by direct link with Command and Data Acquisition station computers.

Command and Data Acquisition. The two CDA sites are also staffed for continuous real-time operations. Their primary functions are to encode and transmit spacecraft commands, and to receive, demodulate, and transfer or process payload data. Commanding and data transfers are controlled by computer-to-computer links with the Operations Control Center. Commanding can be "bent pipe" or independently done at either acquisition site or Control Center. (Data acquisition and command capability at Lannion are extremely limited. See chapter VIII for details, including plans to upgrade this facility.) Data transfer uses a leased commercial satellite system, and involves both global and high-resolution instrument data. Data processing involves high-resolution data using a terrestrial link to Satellite Field Service Stations. The CDA system hardware consists of two Data General Systems 200s having 64K primary and 10 Mb secondary memory.

c. Typical Payload Operations

Common Operations. For all spacecraft payloads, the POES

Command and Control System provides post-launch turn-on, activation or deployment, mission housekeeping, formal anomaly configuration control, and load and temperature management during satellite emergencies. During the orbits immediately after launch, instrument electronics are turned on, and housekeeping status is determined to ensure nominal performance of components such as scan and filter wheel motors. Activation generally involves turning on visible data processing channels where applicable, establishing built-in electronics or radiance calibration modes, and removing protective coverings and Earth shields, or opening cooler doors. Heaters are operated to provide infrared detector cooler decontamination required for proper signal to noise. Activation generally lasts 2 weeks.

In mission mode with instruments operating on a stable platform, the Command and Control System routinely collects and evaluates housekeeping telemetry to verify normal timing, temperature, and power parameters. The technical support facility monitors instrument signals-to-noise ratios from data processed and supplied to the command and control system by the NESDIS Office of Satellite Data Processing and Distribution. To accommodate the discovery, tracking, and resolution of abnormalities in flight, a formal TIROS orbital anomaly review board exists and meets monthly. Participants are NOAA, NASA, spacecraft builders, and instrument builders.

In satellite emergencies involving loss of attitude control, the normal instrument power and thermal environment are threatened. To minimize spacecraft power requirements during these events, instruments are commanded to a known and low-power mode, which generally corresponds to launch configuration (excluding deployables). Instrument temperature is constantly monitored and maintained within survival limits by ground-commanding satellite heaters and louvers as needed. What follows is an outline of some payload-unique operations.

TOVS (HIRS, MSU, SSU). In addition to built-in electronic and radiance calibration modes, which are accomplished each line or basic instrument cycle, the TOVS instruments routinely undergo quarterly or semiannual calibrations involving extended space or blackbody looks. Command timing is critical from the standpoint of data quality, and is generally done by precise, stored onboard computer control. The SSUs are prone to synchronization loss, and are monitored closely in real time and resynchronized as needed. To eliminate Earth-coupling effects on MSU space calibration, the NOAA 6 spacecraft dynamics were modified so that the entire field of view was filled by space for several orbits.

AVHRR. AVHRR-unique operations include switching the channels selected for real-time APT transmissions at each orbit terminator point, performing IR detector patch decontamination, tracking channel noise signature and sync jitter, routinely resynchronizing marginal scan motors, providing extraordinary thermal management for motor lubrication, and monitoring image quality.

SAR. Search and rescue support involves developing a command management plan that serves as a working interface control between NESDIS Satellite Operations, USMCC, NASA, and the Canadian Research Corporation. To date, with SAR systems on two spacecraft, the plan has been used about a dozen times, mostly to configure the spacecraft for satellite-to-ground tests. NESDIS maintains and updates the required command data base.

DCS. Managing real-time transmission conflicts for Argos and coordinating with the local representative of Service Argos are the primary tasks in DCS support. As with the SAR, a coordinated command management plan has been developed and is in use. NESDIS has modified onboard software to ensure continuous reliability in the system's ultrastable oscillators.

SEM. SEM-unique operations consist of weekly electronic calibration, periodic establishment of detector bias values compatible with particle energy environment, and troubleshooting radio frequency interference (RFI). Coordination is maintained with NOAA's Space Environment Laboratory, located in Boulder, Colorado.

SBUV and ERBE. These are the newest payloads in the system, first flown on NOAA 9. Plans are just beginning for routine support. The SBUV requires wavelength calibration, solar calibration, and discrete and swept backscatter data collection modes. Frequencies for each mode range from once a day to once each 14 days.

Both of these instruments, scanner and nonscanner, require solar and internal calibration about every 2 weeks. Calibration and data management are done using new automatic ground scheduling software, and onboard computer-stored execution.

F. COMMUNICATIONS

The DMSP satellites and the NOAA-POES satellites are designed, through their communication networks, to serve two separate purposes and clienteles. The DMSP satellites are designed to serve U.S. Armed Forces during both peacetime and times of international tension and conflict. DMSP satellites encode all data transmissions, direct and recorded. The details of DMSP communications are contained in section E, which describes the DMSP command, control, and communications (C^3) segment. The NOAA-POES satellites, on the other hand, serve the civil weather services. The NOAA satellites are necessarily linked with U.S. membership in the World Meteorological Organization, and as such are a part of many international cooperative efforts. The NOAA-POES communications downlinks are all "in the clear," and broadcast real-time transmissions throughout the world.

Both the DMSP and the NOAA-POES satellites utilize bands in the frequency spectrum set aside for meteorological satellites by the International Telecommunications Union (ITU). Table III-23 lists the frequencies presently in use by the NOAA-POES. Descriptions of the various transmissions are:

Link 1 -- Beacon transmission. Provides direct full-time broadcast of the low data rate instruments on board the satellite. Principal users of this data are data collection platform services and temperature sounding users. One frequency is used on the AM satellite, and the other frequency is on the PM satellite. Use of the beacon frequencies will be discontinued about 1990 in accordance with Consultative Committee on International Radio (CCIR) Recommendation 595.

Link 2 -- VHF real time. Provides APT analog services to users worldwide. Transmits two channels from the AVHRR, one visible and one infrared. One frequency is used on the AM satellite, and the other frequency is used on the PM satellite.

Link 3 -- S-band real-time. Provides high data rate (665 kbps) to HRPT users thoughout the world. These data are real-time data only, not stored data, and contain the output of all the low data rate instruments, plus high-resolution data from all of the AVHRR channels. One frequency is used on the AM satellite, and the other frequency is used on the PM satellite.

Link 4 -- S-band dump to CDAs. Two of the three frequencies listed are used to transmit the stored data to the CDA stations. The HRPT frequency continues to transmit real-time data, while the other two frequencies are being used to dump the stored data.

Link 5 -- DCS uplink. This frequency is used to transmit data from ground-based platforms to the satellite, where they are stored for later transmission.

Link 6 -- Command uplink. This frequency is used by the CDAs to transmit all commands to the spacecraft.

Table III-23
POES Communications Frequencies

Link	Carrier Frequency	Direction
1. Beacon	137.77 MHz 136.77 MHz*	S.-E.
2. VHF Real-Time--APT	137.50 MHz 137.62 MHz	S.-E.
3. S-Band Real-Time--HRPT	1698.0 MHz 1707.0 MHz	S.-E.
4. S-Band Dump to CDAs	1698.0 MHz 1702.5 MHz 1707.0 MHz	S.-E.
5. DCS (Uplink only)	401.65 MHz	E.-S.
6. Command (Uplink only)	148.56 MHz	E.-S.
7. Search and Rescue (Uplink)	121.5 MHz 243.0 MHz 406.05 MHz	E.-S.
8. Search and Rescue (Downlink)	1544.0 MHz	S.-E.

* Use of this frequency will be discontinued about 1990 in accordance with CCIR recommendation 595.

Link 7 --	SAR uplink. The three frequencies listed are beacon frequencies for emergency transmissions that are originated at the site of an aircraft crash or vessel sinking, or when assistance is needed. These are ground-to-spacecraft frequencies, and are received by sensors on the spacecraft and relayed to ground stations.
Link 8 --	SAR downlink. This frequency is used to relay the beacon frequencies received by the spacecraft to ground receiving stations equipped to locate and alert rescue efforts. This is a special frequency set aside internationally for search and rescue.

IV. RELATIVE ANALYSES AND USES OF DMSP AND POES IMAGERS

A. OPERATIONAL LINESCAN SYSTEM (OLS)

1. Instrument Description

A tabular technical comparison of the DMSP Operational Linescan System (OLS) and the NOAA/POES Advanced Very High Resolution Radiometer (AVHRR) is provided in table IV-1. The following discussion compares the two imaging systems in greater detail.

The Operational Linescan System (OLS), first flown in 1976 on the Block 5D spacecraft, is the primary meteorological sensor of the DMSP. The OLS is a two-channel radiometer, but its operation is somewhat different from that of other radiometers (such as the TIROS/AVHRR) in that the mirror oscillates rather than rotates. This back-and-forth sinusoidal motion of the optical telescope system moves the instantaneous field of view of the detectors across the satellite subtrack, with maximum scanning velocity at nadir and reversals at the ends of the scans. The detector size of the optics is dynamically changed to reduce the field of view near the end of each scan, thus maintaining an essentially unchanged "footprint" size on the Earth's surface. The gain of the sensor is also adjusted along the scan line to compensate for larger variations in the reflected light level as the satellite crosses the terminator. Furthermore, through use of a photomultiplier tube, it is possible for the OLS to collect reflected visible radiation at night, with illumination as low as that corresponding to a quarter moon. This unique OLS design is driven by the following important military requirements:

- Constant Spatial Resolution. The OLS is the only operational imager with constant spatial resolution across the entire 1,600 nmi width of the data swath. This capability is vitally important for both strategic and tactical applications. For strategic applications, constant resolution is essential for fast computer processing to meet very stringent forecast timelines. It is also important in tactical direct readout use, where the area of interest (launch or recovery base, refueling area, target, etc.) may not be directly under the spacecraft, but 800 miles away at the edge of the swath.

- Low Light Level Visual Capability. A vital military capability is the conduct of a wide range of operations at night, including combat, rescue, reconnaissance, and resupply missions. The unique capability of the OLS to obtain visible imagery down to the equivalent of one quarter moon light is essential. Further, this ability provides images of the auroral oval position, which are

Table IV-1

Imager Technical Comparison

Characteristic	OLS	AVHRR/2
Spectral Channels	Visible 0.4- 1.1 μm Visible - low light* 0.4- 0.95 μm IR 10.2-12.8 μm * To quarter moon equivalent illumination	Visible 0.58 - 0.68 μm Near IR 0.725 - 1.00 μm IR window 3.55 - 3.93 μm IR window 10.5 - 11.5 μm IR window 11.5 - 12.5 μm
Field of View (resolution)	0.3 nmi-uniform. 3 bands 1.5 nmi-low light visible channel 0.67 mrad IFOV	0.5 nmi at nadir - nonuniform 1.3 mrad IFOV
Optics Size	8 in diameter Cassegrain telescope	8 in diameter telescope
Signal to Noise (NEΔT)	Visible ± 2% albedo Visible - low light ± 5% albedo IR 0.4 K-300 K target	Visible/near IR › 3:1 at 0.5% albedo IR 0.12 K - 300 K target
Dynamic Range	Visible 0-100% albedo equivalent Visible/low light requires quarter moon IR 190-310 K blackbody	Visible/near IR 0-100% albedo IR 0-320 K blackbody
Digitization	Visible-6 bit resolution Visible/low light-6 bit resolution IR-8 bit resolution	Visible/near IR/IR 10 bit resolution
Calibration	Visible/visible low light-none IR: Space/internal blackbody target by command (does not include total system)	Visible/near IR-none IR: space/external blackbody (calibrates total system on each scan line)
Line Rate	11.88 lines/s (5.94 Hz)	6 lines/s
Scan Field of View	±56.24° from nadir, oscillating mirror	±55.4° from nadir 360° mirror rotation 30.8% duty cycle
Weight	295 lb (1)	‹ 65 lb
Power	170 W max. (1)	‹ 30 W
Design Life	3 yr with goal of 4 yr	2 yr
Cost	$12.9 M (1)	$2 M

data and telemetry handling system for spacecraft and all vital to the support of DOD radar and communications systems.

- Automatic Rectification. This is vital to fast computer processing, untouched by human hand, of the OLS data. It is also important for the direct readout tactical terminals to expedite delivery of images to the decision makers.

- Electronic and Radiance Calibration. The automatic calibration of the OLS is described below, and is important to quantification and discrimination of sensed data.

- Sensor Cooler Operation at All Sun Angles. An important military requirement is the ability to select any nodal crossing time in the 24-hour day when driven by operational necessity. The ability to operate at all sun angles is required, and is a unique capability of this system.

2. Spectral and Spatial Resolution

a. Spectral Bands. The spectral bands of the OLS are 0.4 to 1.1 nm for the visible (or L data) and 10.2 to 12.8 nm for the thermal infrared (or T data). Direct readout data at fine (F) resolution (0.6 km) and smoothed (S) resolution (2.8 km) can be received at the tactical terminals; data can also be recorded on board the spacecraft at both the fine and smoothed resolution for transmission to the central receiving stations (low light level nighttime visible data are at 2.8 km resolution). The main features of the OLS are summarized in table IV-2. Figure IV-1 is an example of visible, infrared, and nighttime visible DMSP data.

b. Spectral Bandwidth. In order to optimize the distinction among clouds, ground, and water, two spectral bandwidth channels are required: one in the visible and near infrared region of 0.4 to 1.1 micrometers, and another in the infrared region of 10.2 to 12.8 micrometers. The 0.4 to 1.1 micrometer band is termed the light or L-band in the OLS, while the 10.2 to 12.8 micrometer band is termed the thermal or T-band. The L-band extension into the near infrared region was selected to enhance the ability to distinguish tropical vegetation from water. However, there remain scenes that cannot be properly distinguished using only one of these bands, but can be when both are used. A three-dimensional aspect of the data is provided by the T-band, because cloud height is directly related to cloud-top temperature, which is indicated by readings in this thermal band.

c. Resolution. The low noise requirements for high quality data are measured in the L-band by the signal to noise ratio

TABLE IV-2

OLS DATA SPECIFICATIONS

Environmental Parameters Sensed/Derived

–Measures reflected sunlight and moonlight, and thermal radiation from clouds and the Earth's surface

–Nominal spectral response of detectors

Visible	0.4 – 1.1	micrometers
Low Light Visible	0.45– 0.95	micrometers
Thermal	10.2 –12.8	micrometers

–Derived parameters include cloud imagery, cloud top temperature, sea surface temperature, and auroral imagery

Data Accuracy

–Visible data–6 bit resolution (64 gray shades)

–Infrared data–8 bit resolution (256 gray shades) for objects between 190 and 310 K

–Albedo ±5%

–Sea surface temperature, cloud top temperature nominally accurate to ±5 K, reducible by correcting for moisture down to at best ±2 K

Data Coverage

–Global coverage

–Horizontal swath width 1600 NM

Data Resolution

–Horizontal: 0.3 NM daylight visible
1.5 NM night visible (low light down to 1/4 full moon)
0.3 NM–IR

Constant resolution as a function of scan angle

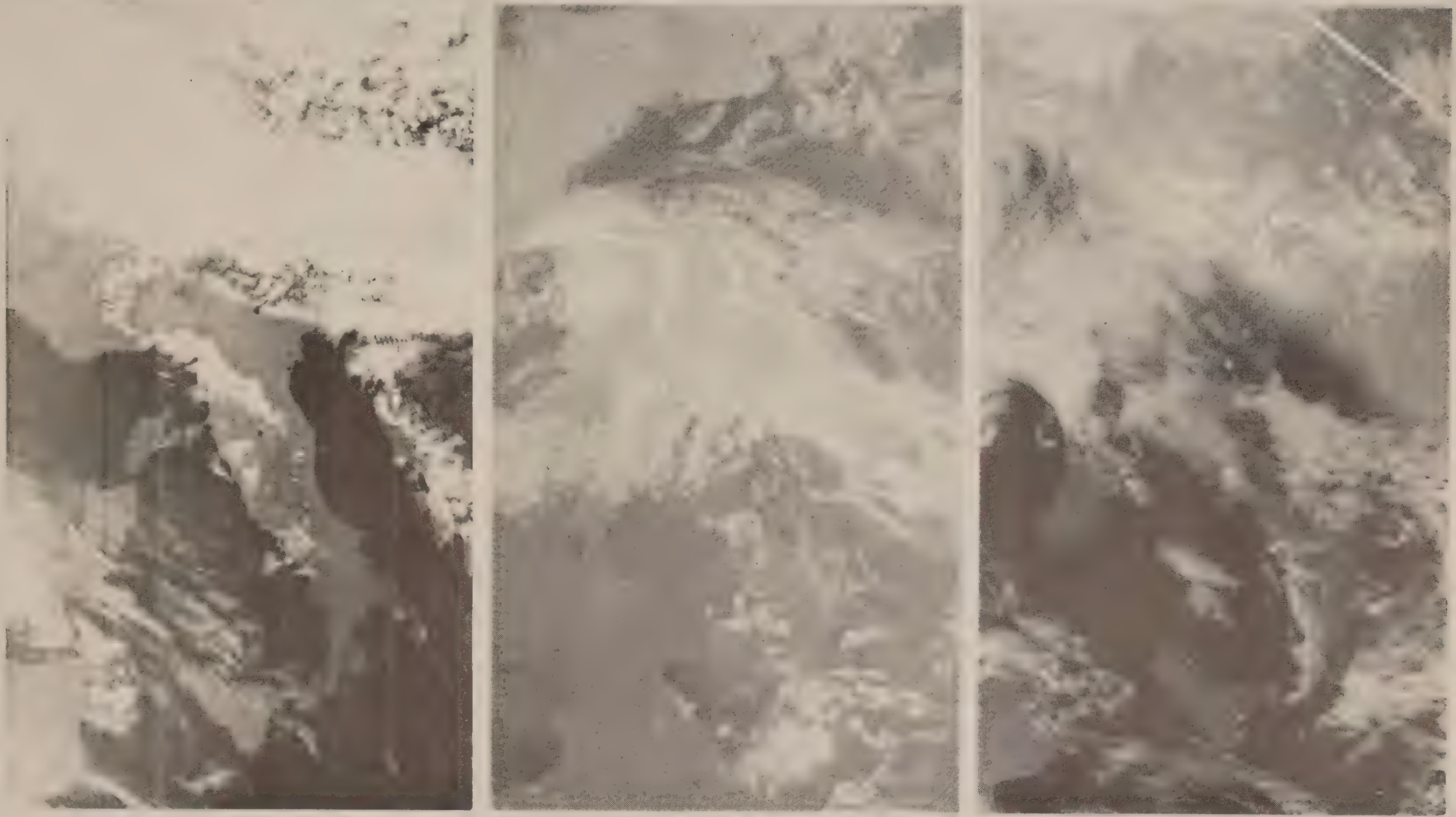
Other Comments

–Primary sensor, on all DMSP spacecraft

–4 tape recorders–40 min of visible + IR at 0.3 NM resolution per recorder
400 min of visible + IR at 1.5 NM resolution per recorder

Figure IV-1
DMSP Visible, Infrared, and Low Light Visible Imagery

Italy



Daytime Visual Spectrum

Day/Night Infrared Spectrum

Nighttime Visual Spectrum

DMSP

(SNR) and in the T-band by the noise effective temperature difference (NETD). High radiometric resolution for high quality data is measured for digital data as quantization or in terms of equivalent SNR. The L-night sensor is required to have an SNR of 6 at half-moon scene illumination levels, and to increase with scene illumination to 200. The L-day sensor is required to have an SNR of 10 at several geocentric degrees on the dark side of the terminator, and to increase with scene illumination to 200. The NETD of the T-band data is required to be less than 1.30 K.

The quantization requirement for both L- and T-band data is nominally either 6 or 7 bits, depending on the geometric resolution.

d. Day, Night, and Terminator Capability. The T-band data are independent of whether the scene is a daytime or nighttime scene. However, the L-band data must have the dynamic range to recover scenes illuminated in subsolar conditions, scenes illuminated by one quarter moon, and all levels in between. Not only must the dynamic range be available, the gain of the L sensor must be switched along the sensor scan to recover scene data. Figures IV-2 and IV-3 show a near terminator orbit, and indicate the path of the sensor line of sight on the Earth scene. On a given scan, the scene signal level may cover a significant range, which requires a compensating change in sensor gain to enable scene data recovery.

e. Glare Rejection. The capability to have the L sensor in the proper gain throughout the sensor scan will not permit data recovery if strong unwanted signal sources cause more sensor response than the scene. In near terminator orbits, where a sensor in sunlight views scenes that are not sunlit, the sun is such a strong L-band source compared to nighttime scenes that even small portions of sunlit spacecraft structure not in the sensor line of sight can produce more solar glare than scene signal. Rejection of solar glare must be sufficient to allow such scenes to be recovered.

f. Glare Suppression. Loss of data due to on-axis scattering of incident sunlight is minimized. This is accomplished by incorporating anti-glare features in the optical/mechanical design of the telescope, and by providing sunshades or sunshields.

For moon orbit glare suppression, the GSS sunshield is used. It consists of first surface specular mirror sunshades that are mounted immediately adjacent to the aperture area of the telescope. These mirrors prevent sunlight from impinging directly on any part of the telescope or surrounding diffuse scattering surfaces. Because they are specular, they also minimize the impingement of primary scatter on these areas.

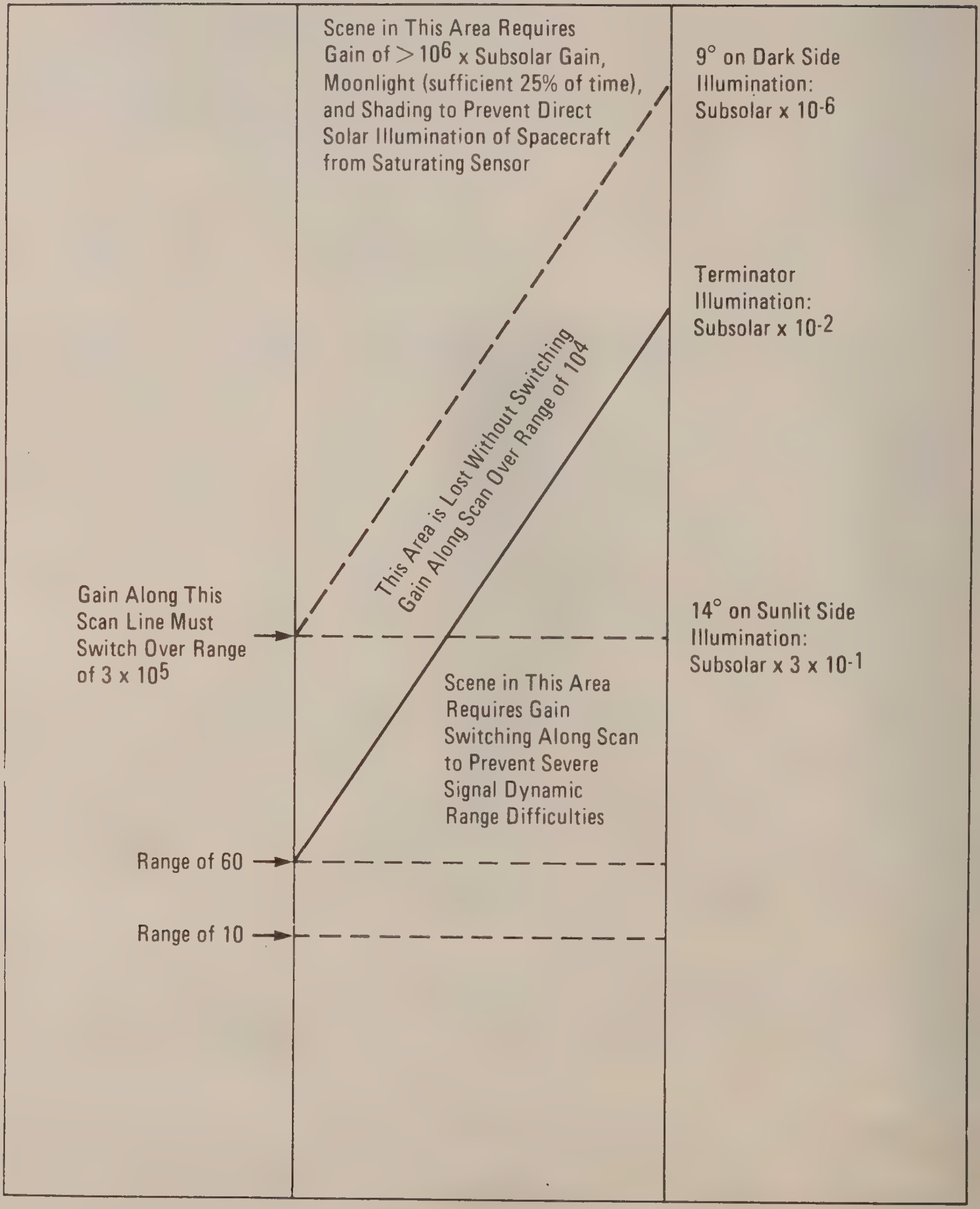

Scene in This Area Requires Gain of > 10^6 x Subsolar Gain, Moonlight (sufficient 25% of time), and Shading to Prevent Direct Solar Illumination of Spacecraft from Saturating Sensor
9° on Dark Side Illumination: Subsolar x 10^{-6}
Terminator Illumination: Subsolar x 10^{-2}
This Area is Lost Without Switching Gain Along Scan Over Range of 10^4
Gain Along This Scan Line Must Switch Over Range of 3 x 10^5
14° on Sunlit Side Illumination: Subsolar x 3 x 10^{-1}
Scene in This Area Requires Gain Switching Along Scan to Prevent Severe Signal Dynamic Range Difficulties
Range of 60
Range of 10

Figure IV-2
Near-Terminator Problem

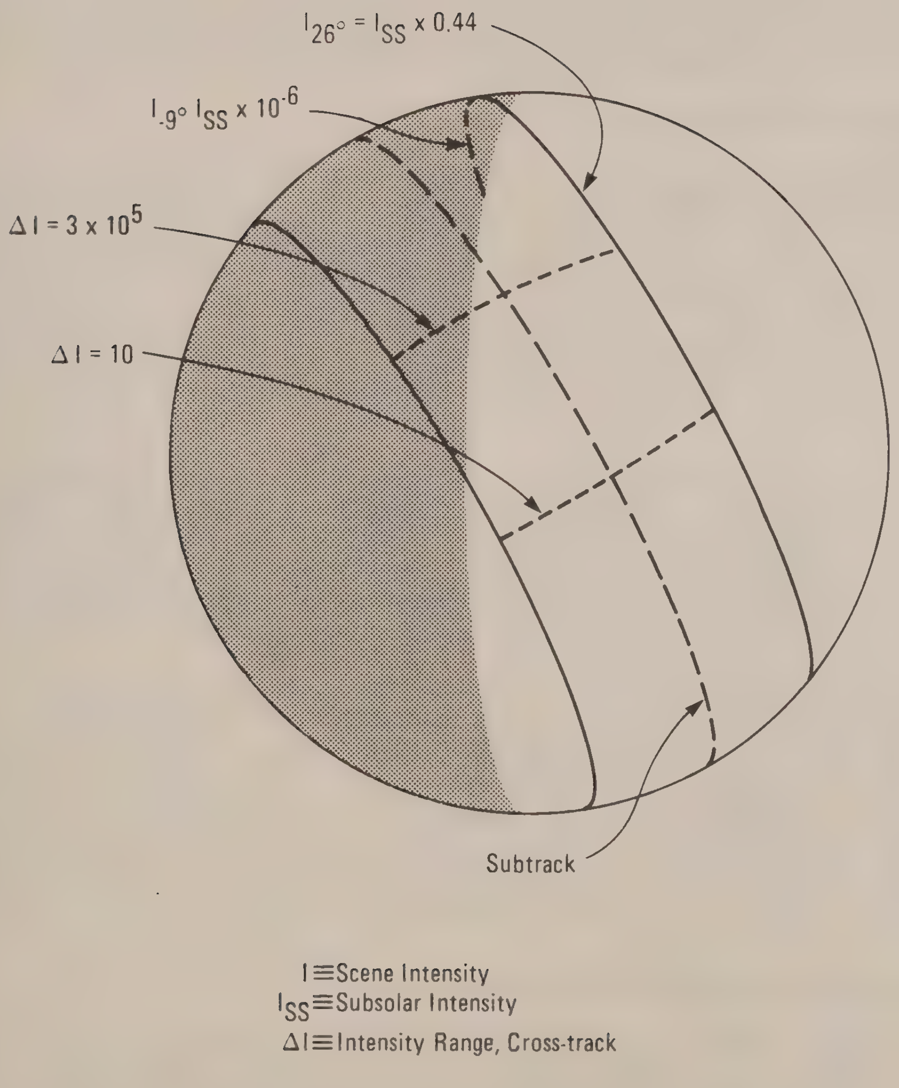

$I_{26^\circ} = I_{SS} \times 0.44$
$I_{-9^\circ}\ I_{SS} \times 10^{-6}$
$\Delta I = 3 \times 10^5$
$\Delta I = 10$
Subtrack
$I \equiv$ Scene Intensity
$I_{SS} \equiv$ Subsolar Intensity
$\Delta I \equiv$ Intensity Range, Cross-track

Figure IV-3
Dynamic Range Requirements for
DMSP OLS Terminator Coverage

This protection is provided for all orbit positions in orbits having sun angles between 65 and 95 degrees.

For terminator orbit glare suppression, a large stationary opaque glare obstructor (GLOB) is erected at the +Z (sunward) end of the spacecraft projecting in the +X (Earthward) direction, so as to prevent sunlight from impinging directly on any part of the telescope or surrounding surfaces.

3. Radiometric Calibration

a. Radiometric Accuracy. The L-band data are required to have an initial absolute accuracy of 8 percent (one sigma). That is to say that, given many sensors, 67 percent of them would indicate an absolute scene radiance within 8 percent of the true scene radiance. Daytime L data are to retain this accuracy over the life of the sensor, while nighttime L data are permitted to degrade in accuracy to 60 percent (one sigma) over the sensor lifetime, since Photo-Multiplier Tubes (PMTs) degrade with use.

The T-band data are required to have an absolute accuracy of 1.5 K (one sigma). In addition, the T-band data are required to have a repeatability among samples of the same scene temperature of 0.25 K (one sigma). The T-band data are required to be linearized, making equivalent blackbody temperature between 210 and 310 K the signal amplitude parameter.

b. T-Channel References. To provide references for calibration and clamp for the T-channel output, a blackbody source is viewed by the detector at each end of scan. The calibration source is attached directly to the main structure and its temperature measured by a thermistor. The clamp source is thermally isolated from the structure on three glass ball joints; a conduction rod attaches to a radiator plate, which cools the source to low temperature by radiation to space (fig. IV-4).

4. Radiometric and Geometric Precision

Thermal fine (TF) resolution data are collected continuously day and night by the infrared detector; light fine (LF) resolution data are collected continuously during daytime only by the silicon diode detector. Fine resolution data have a nominal linear resolution of 0.3 nmi. Because of the quantity of the data collected, it is not possible to store or transmit all of the fine resolution information. Therefore, smoothing or selective collection is required. Storage capacity and transmission constraints limit the quantity of fine resolution data that can be provided in the stored data fine (SDF) mode to a total of 40 minutes of LF or TF data per 10-minute CRS readout.

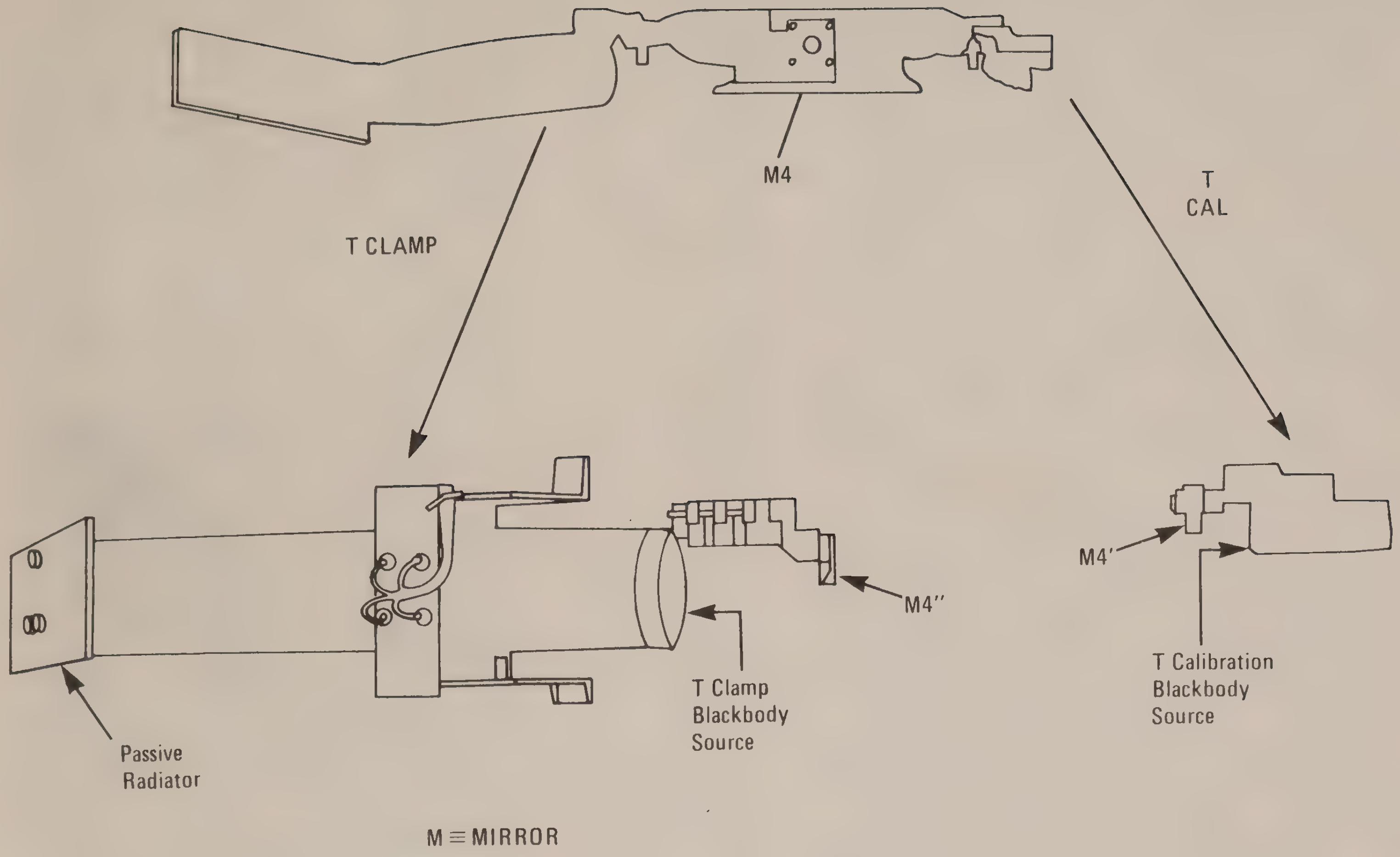

M4
T CLAMP
T
CAL
M4'
T Calibration
Blackbody
Source
M4''
T Clamp
Blackbody
Source
Passive
Radiator
M ≡ MIRROR

Figure IV-4
T Calibration and Clamp

Data smoothing permits global coverage in both thermal smoothed (TS) and light smoothed (LS) data to be stored on the primary tape recorders in the stored data smoothed (SDS) mode. This smoothing is accomplished by analog averaging of the fine resolution input from five resolution cells that are contiguous in the across-track direction, then digitally averaging five such 1 by 5 cell samples in the along-track direction. A nominal linear resolution of 1.5 nmi results. Four hundred minutes of LS and TS data may be transmitted during a single 10-minute CRS readout. All data are processed, stored, and transmitted encrypted in digital form.

In addition, a photomultiplier tube allows collection of LS data under quarter-moon or brighter nighttime conditions at 1.5 nmi nominal linear resolution.

A combination of either fine resolution data and the complementary smoothed resolution data (i.e., LF and TS) can be provided directly to remote sites in the real-time data (RTD) mode. In this mode, only the analog, across-track smoothing is accomplished before transmission. Along-track smoothing is done by the ground processing equipment.

The visual daytime response of the OLS is in the spectral range of 0.4 to 1.1 micrometers, chosen to provide maximum contrast between Earth, sea, and cloud elements of the image field. The infrared spectral response of 10.2 to 12.8 micrometers was chosen to optimize detection of both water and ice crystal clouds.

5. Imaging/Radiometric Applications

The OLS is the primary sensor aboard the spacecraft providing visible and infrared imagery. The imagery is used to analyze cloud patterns in support of a wide range of military requirements, from photomapping to issuing severe weather warnings. A passive microwave temperature sounder (SSM/T) provides data for profiling atmospheric temperatures on a global basis from the Earth's surface to altitudes above 30 km.

The OLS imagery is the data source for the Satellite Global Data Base (SGDB) at AFGWC. The SGDB is used as primary input into the AFGWC real-time nephanalysis model, and in building hard copy photographic quality display images. These products permit support to detection and monitoring of major weather systems; location and intensity estimation of hurricanes and typhoons; creation of three-dimensional cloud analysis for numerous applications; discrimination of cloud and snow; computation of soil moisture and an index of vegetation growth; and location and characterization of auroral activity (using twilight level visible capability--see figure XI-2).

A global cloud imager is used by military weather forecasters to detect and monitor developing weather patterns and follow existing weather systems. The data help identify severe weather, such as thunderstorms, determine the location and intensity of tropical cyclones, and form three-dimensional cloud analysis of various weather conditions. The automated global cloud analysis performed at AFGWC is used as input to their global numerical cloud forecast models (fig. IV-5).

The FNOC uses DMSP imagery along with sea surface temperature data in its global ocean forecasting program. The imagery assists in interpreting the location and intensity of oceanic extratropical cyclones for quality control prior to intialization of numerical forecast models. Navy tactical sites (aircraft carriers) use DMSP imagery to provide insight into atmospheric and oceanographic processes occurring in their operational areas. In addition to observing existing weather systems, various aspects of sunglint and anomalous gray shade patterns permit determination of sea state, low-level wind direction, atmospheric moisture, sea surface temperature gradient, and oceanic fronts and eddies (tables IV-3 and IV-4A, B, and C).

a. Image Products. The following products are produced at AFGWC as imagery from DMSP data:

- Fine data — 0.3 nmi resolution both visual and IR
- Global area coverage — 1.5 nmi resolution both visual and IR
- SGDB:
    - Northern Hemisphere polar stereographic. This array consists of a 4096 by 4096 map array resulting in a pixel resolution of approximately 5.6 km. Data that have a resolution higher than 5.6 km are repeated to fill in the appropriate number of SGDB pixels. Each pixel of data is represented by a single 6-bit gray shade value ranging from 1 to 63. The array is aligned with the prime longitude at 80° W.
    - Southern Hemisphere polar stereographic. This projection of the SGDB is defined in the same manner as the Northern Hemisphere polar stereographic projection.
    - Mercator. This projection of the SGDB is a 4096 by 2716 map array covering the region of the Earth between 45° N. and 45° S. Map resolution at the Equator is 9.8 km.

- X2 expanded data

- X4 expanded data

- Various temperature enhancement products (e.g., contoured IR)

b. Strategic Defense Mission Area. DMSP data provide information on winds, atmospheric density, clouds, severe weather, tropical cyclones, electron density profiles, and total electron content that affect air defense aircraft, anti-satellite systems (ASAT), and ground-based lasers.

c. Theater Warfare Mission Area. DMSP data provide information on winds, atmospheric density, clouds, severe weather, and tropical cyclones that affect fixed-wing and helicopter operations as well as cruise missiles.

d. Force Projection and Mobility Mission Area. DMSP data provide information on winds, atmospheric density, clouds, severe weather, and tropical cyclones that affect inter- and intratheater airlift and aerial refueling.

e. Mission and Support Areas. DMSP data provide information on winds, atmospheric density, clouds, severe weather, tropical cyclones, electron density profiles, and total electron content that affect various weapon systems involved in such mission support areas as rescue and recovery, space launch and orbital support, surveillance, and reconnaissance.

f. Detailed Weapon System and Supporting Parameters. The Air Force Systems Command Electronic Systems Division Technical Report "ESD-TR-84-198" WX 2000 Technical Report, Volume I, 20 September 1984, pages 3-38 and 4-54 to 4-61, relates mission areas supported to specific systems.

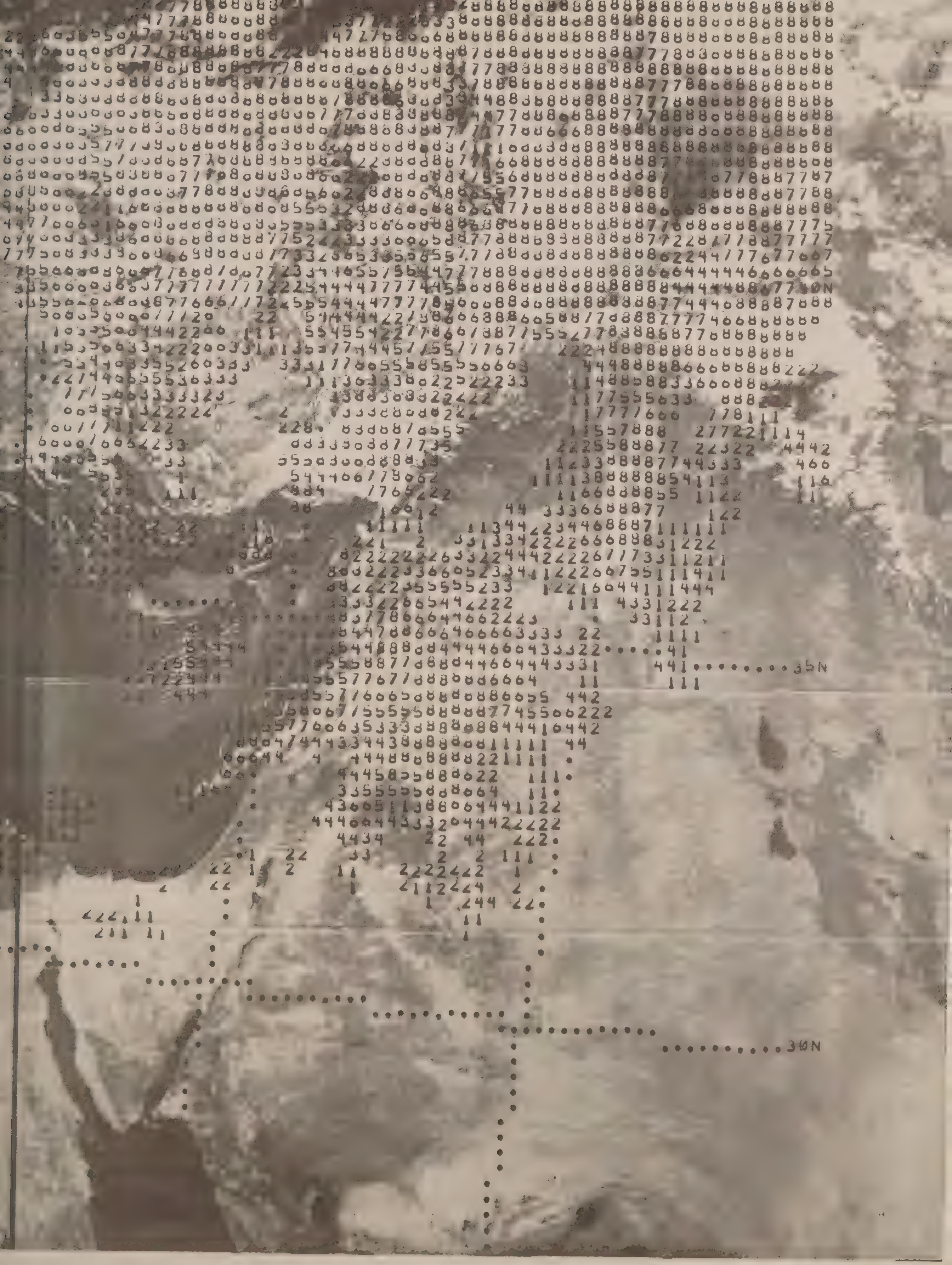
g. Noncentralized Data Applications. Air Weather Service and Navy forecasters use OLS imagery and will use SSM/T, SSM/T-2, SSM/I, and LIDAR mission sensor data when they become available at tactical direct readout sites. These data are applied for three primary purposes:

- To develop mission-tailored forecasts for Air Force, Army, and Navy missions

- To provide aircrews and command and control (C^2) decision makers with the environmental intelligence

- To provide operational commanders with environmental intelligence for tactical weapon system employment

Figure IV-5
AFGWC Automated Cloud Analysis



AFGWC Automated Cloud Analysis

TABLE IV-3

DMSP DATA PROCESSING/APPLICATION (CURRENT)

Sensor	Data Type	Current Spacecraft	Sensor Operational	Processed at AFGWC	Applied at AFGWC	Processed at FNOC	Applied at FNOC	Products/Applications
OLS	Visual and infrared cloud imagery	F6/F7	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Provides global cloud imagery for the real-time cloud analysis data base which is then used by several cloud forecast models and other application programs.
SSM/T	Temperature soundings	F7	Yes	Yes	Yes^{1}	No	No	Provides approximately 15,000 soundings per day to the AFGWC upper air data base, which is used by several models e.g., HIRAS, Point Analysis, etc. FNOC will obtain SSM/T data through shared METSAT for use in numerical models.
SSH-2	Temperature soundings	F6	No	N/A	N/A	N/A	N/A	Could provide approximately 16,000 soundings per day to the AFGWC upper air data base. Applications are same as the SSM/T. One sensor to fly; AFGWC does not intend to process the data^{2}. FNOC will.
SSJ/4	Precipitating energetic particles	F6/F7	Yes/Yes	Yes/Yes	Yes/Yes	No/No	No/No	Data are input to the aurora boundary model.
SSB/A SSB/S SSB/X	Location and energy spectrum of gamma and x-ray sources	F6/F7	No/Yes	No/No	N/A	No/No	No/No	Air Force Technical Applications Center (AFTAC) sensor. Data are shipped from AFGWC to AFTAC.
SSI/E	Average ion mass, electron density and electron and ion temperatures at spacecraft altitude	F6/F7	No/Yes	N/A /Yes^{3}	N/A /Yes	No/No	No/No	Data are used to determine the scale height of the topside ionosphere, which is used in a global ionospheric specification program.

Notes:
1. Data available below 30,000 feet.
2. Requires approximately 1,000 work hours of software development for each sensor.
3. Currently only the electron data are being processed.

TABLE IV-4A
MILITARY MISSIONS VERSUS ENVIRONMENTAL PARAMETERS--AIR FORCE

	Strategic Offense	Strategic Defense	Airlift	Tactical Air	Surface Resource Protection	Air Base Group	Air Refueling	Combat Rescue	Space Transportation	Communications	Intelligence	Research Develop-ment Acquisition	Other (Includes SSP and NCA)
Sea State	X	I	X	X	X	X	X	X	X		X	X	X
Soil Moisture	I		X	X				X	X		X	X	
Vegetation	I	I	I	X	I			I	I	I	I	I	
Albedo	I	I	I	X	I		I	I	I	I	X	X	X
Solar X-Ray Radiation	X	X	X	X			X	X	X	X	X	X	X
Spectral Line Images	X	X	X	X			X	X	X	X	X	X	X
Solar Proton Emissions	X	X	I				I	I	X	X	X	X	X
Solar Wind	X	X	X	X			I	I	X	X	X	X	X
Electron Density Profiles	X	X	I				I	I	X	X	X	X	X
Δ Ne/Ne	X	X	I				I	I	X	X		X	X
Total Electron Content Beacons		X							X	X	X	X	X
Magnetic Field	X	X		X	X				X	X	X	X	X
Auroral Emissions	I	X	I				I	I	X	X	I	X	I
Precipitating Electrons		X							X		X	X	X
Magnetospheric Trapped Particles									X		X	X	

X – Directly Supports a Mission Area

I – Indirectly Supports a Mission Area

TABLE IV-4A
MILITARY MISSIONS VERSUS ENVIRONMENTAL PARAMETERS- -AIR FORCE (CONCLUDED)

	Strategic Offense	Strategic Defense	Airlift	Tactical Air	Surface Resource Protection	Air Base Group	Air Refueling	Combat Rescue	Space Transportation	Communications	Intelligence	Research Development Acquisition	Other (Includes SSP and NCA)
Temperature	X	X	X	X	X	X	X	X	X	X	X	X	X
Skin Temperature	X	X	X	X	X	X	X	X	X	X	X	X	X
Surface Pressure	X	X	X	X	X	X	X	X	X	X	X	X	X
Neutral Density									X		X	X	X
Absolute Humidity	X	X	X	X	X	X	X	X	I	X	X	X	X
Pressure											X	X	X
Wind	X	X	X	X	X	X	X	X	X	X	X	X	X
Clear Air Turbulence	X	X	X	X			X	X	X				
Clouds	X	X	X	X	X	X	X	X	X	X	X	X	X
Liquid Water Content	X	X	X	X	X	X	X	X	I	X	X	X	X
Precipitation	X	X	X	X	X	X		X	I	X	X	X	I
Visibility	X	X	X	X			X	X	I		X	X	X
Optical Turbulence	X	X		X					X	X	X	X	
Atmospheric Transmission	X	X		X						X	X	X	I
Refractivity	I	X	I	X	I		I		X	X	X	X	X
Snow Cover	X	X	X	X	X		X	X			X	X	X
Ice Cover	X	X	X	X	X		X	X			X	X	X

X – Directly Supports a Mission Area

I – Indirectly Supports a Mission Area

TABLE IV-4B
MILITARY MISSIONS VERSUS ENVIRONMENTAL PARAMETERS--ARMY

	Airborne	Air Defense	Artillery	Aviation	Amphibious Warfare	Engineering	Infantry	Armor	C^3	Intelligence	Logistics	Nuclear, Biological, Chemical
Sea State					X				I	X		
Soil Moisture	X	X	X	X	X	X	X	X		X	X	X
Vegetation	X	X	X	X	X	X	X	X	I	I	X	X
Albedo			I						I	X		
Solar X-Ray Radiation									X	X		
Spectral Line Images									X	X		
Solar Proton Emissions									X	X		
Solar Wind									X	X		
Electron Density Profiles									X	X		
Δ Ne/Ne									X			
Total Electron Content Beacons									X	X		
Magnetic Field									X	X		
Auroral Emissions									X	I		
Precipitating Electrons										X		
Magnetospheric Trapped Particles										X		
Temperature	X	X	X	X	X	X	X	X		X	X	X
Skin Temperature	X	X	X	X			X	I		X		I
Surface Pressure	X		X	X	I	I	I	I		X	X	X
Neutral Density			X		I					X		X
Absolute Humidity	X	X	X	X	I	X	X	X		X	X	X
Pressure	X	X	X	X	I	I				X		X
Wind	X	X	X	X	X	X	X	X		X	X	X
Clear Air Turbulence	X		X	X	I							X
Clouds	X	X	X	X	X		X	X		X	X	X
Liquid Water Content	X	X	X	X	I	I	I	I		X	X	X
Precipitation	X	X	X	X	X	X	X	X	I	X	X	X
Visibility	X	X	X	X	X	X	X	X		X	X	X
Optical Turbulence	I	X	X	X	X	I	X	X	I	X	I	I
Atmospheric Transmission	X	X	X	X	X		X	X	X	X		
Refractivity			X	X	X		X		X	X		
Snow Cover	X	X	X	X	X	X	X	X		X	X	X
Ice Cover	X	X			X	X	X	X		X	X	X
Flood/Standing Water	X	X	X	X		X	X	X	X	X	X	X
Water Temperature	I			X	X	X	X			X	X	X
Severe Weather	X	X	X	X	X	X	X	X	X	X	X	X

X – Directly Supports a Mission Area
I – Indirectly Supports a Mission Area

TABLE IV-4C
MILITARY MISSIONS VERSUS ENVIRONMENTAL PARAMETERS--NAVY

	Anti-Air Warfare	Anti-Submarine Warfare	Anti-Surface Warfare	Strike Warfare	Amphibious Warfare	Mine Warfare	Special Warfare	Mobility	C3	Intelligence	Electronic Warfare
Sea State	X	X	X	X	X	X	X	X	I	X	I
Soil Moisture				I	X		X			X	
Vegetation				X	X		X		I	I	I
Albedo									I	X	I
Solar X-Ray Radiation									X	X	X
Spectral Line Images									X	X	X
Solar Proton Emissions									X	X	X
Solar Wind									X	X	X
Electron Density Profiles									X	X	X
Δ Ne/Ne									X		X
Total Electron Content Beacons									X	X	X
Magnetic Field			X						X	X	X
Auroral Emissions									X	I	X
Precipitating Electrons										X	
Magnetospheric Trapped Particles										X	
Temperature	I		X	X	X		X			X	I
Skin Temperature	I									X	
Surface Pressure	X		I	X	I		I			X	
Neutral Density					I					X	
Absolute Humidity	I		I	I	I		I			X	
Pressure	I		I	X	I					X	
Wind	X	X	X	X	X	I	X	X		X	X
Clear Air Turbulence	X		I	X	I						
Clouds	X	I	X	X	X	I	X			X	
Liquid Water Content	X		I	X	I					X	I
Precipitation	X	X	X	X	X	I	X	X	I	X	I
Visibility	X	I	X	X	X	I	X			X	X
Optical Turbulence	X		X	X	X		I		I	X	I
Atmospheric Transmission	X	I	X	X	X		I		X	X	X
Refractivity	X	I	X	X	X		I		X	X	X
Snow Cover	X			X	X	I	X			X	
Ice Cover	X	X	X	X	X	I	X			X	

X – Directly Supports a Mission Area
I – Indirectly Supports a Mission Area

These data are an extremely valuable source of meteorological and oceanographic information in support of worldwide military operations, especially in areas where conventional weather observations are sparse, and in hostile areas where data are unavailable. An analysis of these DMSP sensor data is integrated with other surface and upper-air analyses to establish a baseline for developing forecasts for specific terminals, routes, areas, flights, and targets. Once these forecasts are prepared, they are used in conjunction with imagery/mission sensor data for flight weather briefings to aircrews, for mission planning and operational briefings to C^2 decision makers, and for tropical storm warnings to DOD customers.

OLS imagery depicts cloud types and cloud patterns as well as cloud free areas. OLS data identify the location, extent, and the development of significant weather systems; the location of jet streams, troughs, and ridges; and the areas of potential for turbulence and icing. This information is briefed to aircrews and C^2 personnel to make decisions on:

- The best route of flight, operational area/target, and arrival/alternate stations to avoid or reduce the threat of severe weather (i.e., thunderstorms, turbulence, and icing).
- The best route of flight or operational area based on the wind regime (i.e., jet stream, head wind, tail wind).
- The best operational area/target for missions requiring cloud-free areas (e.g., refueling, electro-optical weapon missions).
- The need to cancel/delay/change missions based on the enroute, area/target, or arrival/alternate stations weather. This includes launch/reentry of STS, ICBMs, etc.

6. Data Availability

The DMSP spacecraft operate in a near-polar, circular, sun-synchronous orbit with a nominal altitude of 450 nmi (833 km). The OLS scan parameters were designed to provide contiguous global coverage. One complete orbit takes 101 minutes; consequently, each satellite images the entire Earth in about 12 hours.

DMSP satellites provide weather data on a real-time basis to the Air Force's Air Weather Service and the Navy's Oceanography Command, and can store the data in onboard recorders for later transmission to Air Force readout sites at Fairchild AFB, Washington, or Loring AFB, Maine. Recorded data are also received in Hawaii at a remote tracking station managed by the AFSCF at Sunnyvale AFS, California.

Data are relayed by commercial satellites from both readout sites and the Hawaii Tracking Station to the AFGWC at Offutt AFB, Nebraska, and the FNOC at Monterey, California.

For a given geographic location, tactical ground terminals can provide military commanders in the field with photographic-like prints of regional cloud cover. Figure IV-6 is an example of imagery from a DMSP tactical terminal. The Mark IV mobile ground terminal is a compact unit consisting of the 10 ft (3m) parabolic antenna, the Mark IV van, and an auxiliary power generator. With the antenna and generator stored in the van, the Mark IV transportable terminal is compact enough to be carried in a C-130 aircraft (fig. II-3).

As DMSP satellites pass overhead, the tactical ground terminals receive pictures of a local section of Earth and its cloud cover. Weather data transmitted from the DMSP satellites to the ground terminal can be gridded and labeled for clarification. Mark IV technology also permits meteorologists to enlarge and print selected portions of infrared and visual weather data from both the military DMSP and civilian (NOAA) satellites.

The DMSP Tactical Terminals can receive real-time visible and infrared cloud imagery from any DMSP and NOAA polar-orbiter satellite. The imagery is obtained each time one of the satellites passes within line-of-site (5° above the horizon) of the terminal. Two, or sometimes three, consecutive passes of each satellite are within range of the terminal every 12 hours. Therefore, the data refresh rate is dependent on the number of polar-orbiting satellites in orbit. The maximum geographic coverage for a pass received at the terminal is 1,600 nmi in width and approximately 3,300 nmi in length.

Each terminal has a meteorological satellite coordinator (MSC) assigned. The MSC determines which passes will be taken based on requirements of supported C^2 organizations. After a satellite pass is received and processed, a hard copy of the imagery is relayed to a weather function via a laser facsimile dissemination system, or by hand carrying the imagery. The weather function uses the imagery to prepare forecasts and brief aircrews or C^2 personnel, etc., in support of the C^2 mission.

B. SENSOR SYSTEM MICROWAVE IMAGER (SSM/I)

1. Spectral and Spatial Resolution

a. Spectral Bands. The scanning multichannel microwave radiometer (SSM/I) is a four-frequency imaging microwave radiometer (tables IV-5 and IV-6). It has been designed and built by Hughes Aircraft and will measure dual-polarized microwave radiation from the Earth's atmosphere and surface at frequencies of 19.35, 37, and 85.5 GHz. The fourth frequency at 22.3 GHz measures vertically polarized radiation in a water vapor absorption band. A variety of geophysical parameters can be derived from these seven channels of data, as demonstrated through laboratory, aircraft, balloon, and spacecraft experiments carried out since the early 1960's. The microwave measurements of the Earth's surface have the advantage of being relatively insensitive to cloud cover, and can be made under nearly all weather conditions.

b. Resolution. The sensor spins at 31.5 rpm, which gives a 1.9 second period during which the spacecraft ground track moves 12.5 km. The constant scan and sample rates are synchronized from a common frequency reference, which results in uniform footprint sizes and scene station spacing (distance between adjacent footprint centers) across the swath. The spacing is 12.5 km both along track and along scan at the highest frequency, and 25.0 km in both directions at all lower frequencies. Both polarization channels at each frequency are sampled nearly simultaneously to assure registration of the channel pairs. Effective field of view values include the effects of cross track antenna beam smear resulting from scan motion during the radiometer integration interval.

2. Radiometric Calibration

The sensor points forward to scan at an Earth incidence angle of 53.1 degrees. It measures hot and cold calibration sources during each rotation. The hot source is housed onboard the spacecraft, and its temperature is monitored by three redundant temperature sensors. The cold reference source is the sky background. The SSM/I swath width is 1,394 km. After about 1 day, or 14 full orbit revolutions, the surface swath largely overlaps the first orbit. Tracks N and N+14 are separated by about 4.7 degrees and overlap by about 63 percent. Thus, about two thirds of the Earth's surface will have repeat coverage on successive days.

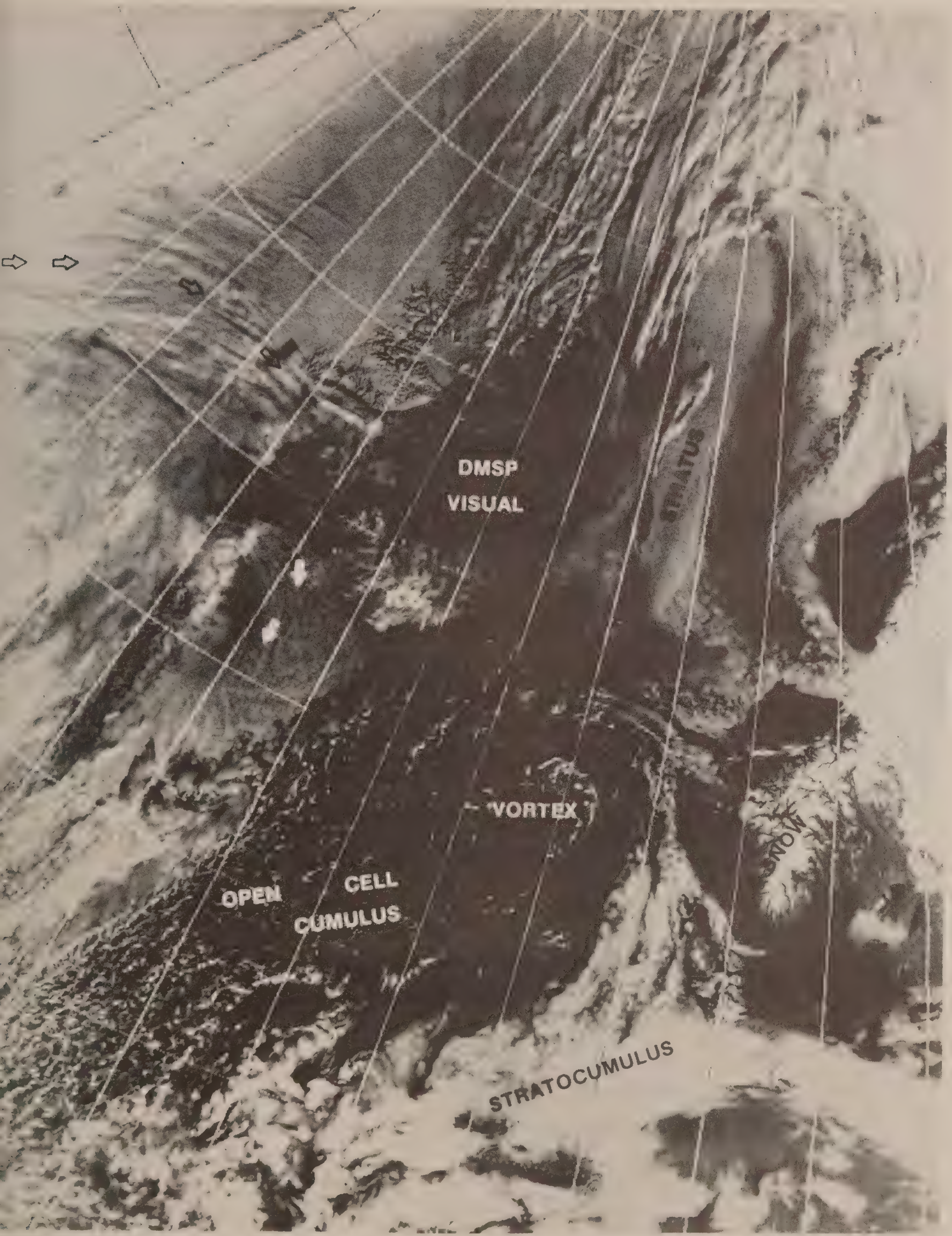
SSM/I parameter performance requirements have been formulated for nine parameters. The parameters include ocean surface wind speed, ice coverage, ice age, ice edge location, precipitation rate over land, soil moisture, cloud water, liquid water (cloud droplets plus rain drops), and precipitation rate over water.

3. Radiometric and Geometric Precision

Table IV-7 gives resolution and measurement accuracy requirements for the SSM/I sensor.

Figure IV-6
DMSP Tactical Imagery

From Marine Corps MARK IV Terminal Assigned to
Marine Air Base Squadron 14 (MASS-14) Deployed to
Bodo, Norway, 17 MAR 84. Visible Imagery.


DMSP
VISUAL
STRATUS
VORTEX
OPEN CELL CUMULUS
SNOW
STRATOCUMULUS

Imagery From Marine Corps
DMSP Tactical Terminal

TABLE IV-5
SSM/I DATA SPECIFICATIONS

Environmental Parameters Sensed/Derived

–Measures microwave radiation emitted and reflected by atmosphere and Earth's surface

–Spectral channels:

19 GHz, H&V polarization
22 GHz, V polarization
38 GHz, H&V polarization
85 GHz, H&V polarization

–Derived parameters include ocean wind speed, soil moisture, rain rate, cloud water, liquid water, sea ice, total water vapor, land skin temperature, and snow parameters

Data Accuracy

–Ocean surface wind speed: ±2 m/sec (3-25 m/sec)

–Soil moisture: dry–saturated

–Precipitation rate: ±5 mm/hr (0-25 mm/hr)

–Cloud water: ±0.1 kg/m^2 (0-1 kg/m^2)

–Liquid water: ±0.2 kg/m^2 (0-6 kg/m^2)

–Ice concentration: ±12%

–Age: 1st year, multiyear

–Edge location: ±12.5 km

Data Coverage

–Daily global coverage with gaps below 65° latitude

–Horizontal swath width 697 NM

Data Resolution

–Horizontal resolution 12.5 NM for all parameters except ice age and soil moisture, 25 NM

Other Comments

–First flight S-10

–Will fly on all future DMSP spacecraft except S-8 and N-ROSS

–Horizontal resolution limited by antenna size

TABLE IV-6
SSM/I FUNCTIONAL SYSTEM REQUIREMENTS

Parameters	Frequency Ranges (GHz)	Polarization (V, H)	Earth Incidence View Angle (Deg)	System Noise Delta-T (K)	Radiometric Calibration Accuracy (K)	Resolution Geometric Goal (km)
Precipitation	2 Frequencies					
Over Land						
Areas	35 to 50	V&H	50–55	0.8	1.5	25
	80 to 100	V&H	50–55	0.8		
Ocean Surface	3 Frequencies					
Wind Speed						
	19.35	H	50–55	0.75	1.5	25
	22.235	V	50–55	0.75		
	30 to 40	V&H	50–55	0.5		
Ice-concentration	1 Frequency					25
Age,						50
Edge Location	19.35 or 37	V&H	50–55	1.5	2.0	25
Soil Moisture	1 Frequency					
	1.4 to 19	V&H	50–55	1.0	1.5	50
Cloud Water	3 Frequencies					
Over Land	19	V&H	50–55	0.75	1.5	2.5
	37	V		0.5		
	85	V				
Over Ocean	19	H		0.75		
	22	V		0.75		
	37	V&H		0.5		
Liquid Water	2 Frequencies					
Over Land	37	V&H		0.5		
	85	V&H				
Over Ocean	3 Frequencies					
	19	H		0.75		
	22	V		0.75		
	37	V&H		0.5		
Precipitation	3 Frequencies					
Over Water	19.35	H				
	22.235	V				
	30 to 40	V&H	50–55	1.0	1.5	25

TABLE IV-7
SSM/I GEOMETRIC RESOLUTION (km)

Frequency (GHz)	Polarization Pol	IFOV		Effective FOV*		Geometric Mean		Scene Station Spacing
		A–T*	X–T**	A–T	X–T	IFOV***	Effective	
19.35	V	68.9	41.4	68.9	44.3	53.4	55.3	25
	H	69.7	40.8	69.7	43.7	53.3	55.1	25
22.235	V	59.7	36.3	59.7	39.6	46.6	48.6	25
37	V	35.4	22.1	35.4	29.2	28.0	32.2	25
	H	37.2	21.0	37.2	28.7	28.0	32.7	25
85.5	V	15.7	9.5	15.7	13.9	12.2	14.8	12.5
	H	15.7	9.5	15.7	13.9	12.2	14.8	12.5

* A–T = Along Track Dimension

** X–T = Cross Track Dimension

*** IFOV is Equivalent 3dB Antenna Footprint; Effective FOV Includes Cross Track Antenna Beam Smearing

4. Imaging/Radiometric Applications

See tables IV-3 through IV-6 and IV-8.

a. SSM/I. This sensor would provide several valuable measurements, and in some cases the only measurements, of parameters that are needed to support current and future DOD missions. The types of parameters and the significance of the sensor are as follows:

- Land Surface Moisture. The sensor provides the only source of measurement.
- Land Surface Temperature. The sensor provides the only source of measurement in data-sparse or data-denied areas.
- Snow Depth. The sensor provides the only source of measurement in data-sparse or data-denied areas.
- Rainfall Intensity/Accumulation. The sensor provides the only source in data-sparse or data-denied areas.
- Ocean Surface Wind Speed. The sensor provides the only extensive source of this parameter.
- Cloud Water Content/Liquid Water Content. The sensor provides the only source of measurement.
- Ice Cover/Age. The sensor provides the only all-weather source of measurement.

b. Applications of SSM/I Measurements. These measurements are integrated with available conventional data to develop forecasts primarily in support of Arctic operations, electro-optical (E/O) systems, Army and Marine Corps ground operations, aircraft operations, ship navigation information, ocean wave forecasting, ocean surface ambient noise, submarine surfacing, and tropical cyclone warnings. These forecasts are then briefed to appropriate personnel to make decisions on:

- Trafficability of Army forces and equipment based on land surface moisture, rainfall accumulation, and snow depth.
- Selection of enemy targets when using E/O weapons. The target must stand out from its background. The land surface temperature, moisture, snow cover, rainfall intensity, ice cover, and cloud water content/liquid water content are critical factors in determining if the target will stand out or not.

TABLE IV-8
DMSP DATA PROCESSING/APPLICATION (FUTURE)

Sensor	Data Type	Spacecraft	AFGWC Software Status	Products/Applications
SSI/ES	Average ion mass, electron density and density gradient, electron and ion temperatures at spacecraft altitude.	S8-20	Operating	Data will be used to determine the scale height of the topside ionosphere which is used in a global ionospheric specification program. Data may also be used in an ionospheric scintillation model to determine the degree of disturbance of the ionosphere in the high-latitude zone.
SSM/I	Ocean surface wind speed, ice coverage and age, areas and intensity of precipitation, cloud water content, land surface moisture and temperature, and snow depth	S9-20	Evaluation stage	U.S. Navy will supply AFGWC with ocean surface wind fields.[1] Land surface moisture data will be used by the AGROMET model. The U.S. Navy Joint Ice Center will use the ice data and provide a data base to AFGWC. Precipitation data will be used in the AGROMET model and by tropical and severe weather forecasters. Cloud water content and surface temperature will be input for the cloud analysis model. Snow depth will be used by the snow depth analysis model. FNOC will use SSM/I data in numerical models. Mosaic imagery will be processed for display. FNOC will supply certain data for NESDIS archives through shared METSAT.
SSM/T-2	Moisture soundings	S13-20	Contract[2]	Soundings will reside in the upper air data base which will be used by several models, e.g., HIRAS, Improved Point Analysis Model (IPAM), etc.
SSUV	Auroral boundary electron density profiles	S16-20	Initial planning	Data will supplement the OLS and SSJ/4 as input to the Auroral Boundary Model. Electron density profiles will be integrated to provide Total Electron Content (TEC).
LIDAR	Atmospheric wind profiles, aerosol concentration, cloud top height	S18-20[3]	Initial planning	Data will reside in the upper air data base which will be used by several models, e.g., cloud forecast models, etc.

Notes:
1. Requires shared METSAT processing to be operational.
2. The sensor contractor will provide software to build the moisture soundings into the AFGWC upper air data base (same as SSM/T software).
3. Initial system will be non-scanning.

- Feasibility of ocean resuce missions based on ocean wind speeds and ice cover.

- Protective actions required for installation/mission when rainfall intensity/accumulation indicate potential flooding.

- Protective actions required for installation/mission when a tropical cyclone is approaching (based on ocean wind speeds).

- Support to national intelligence collection systems and ICBM systems.

- Feasibility of submarine surfacing based upon ice age.

- Navigation of ships in the vicinity of ice based upon ice edge information.

- Anti-submarine warfare support based upon wind speed that relates to wave forecasts used to determine ambient noise factors.

- Wave forecasts to determine areas of safe ship operations (e.g., underway replenishment).

- Support to SLBM forces.

- Arctic submarine and anti-submarine warfare operations support by providing the ability to identify surfaceable features, such as polynyas and leads, and identifying the age of the ice, from which its toughness and thickness can be deduced.

5. Data Availability

SSM/I data will be available initially only at AFGWC and FNOC, but ultimately at tactical terminals.

C. ADVANCED VERY HIGH RESOLUTION RADIOMETER (AVHRR/2)

1. Instrument Description

The Advanced Very High Resolution Radiometer (AVHRR/2) is a five channel instrument sensitive to visible, near infrared, and infrared window portions of the spectrum. The instrument channelization has been chosen to permit multispectral analyses for hydrologic, oceanographic, and meteorological purposes. The visible and near infrared channels are used to discern clouds, land water boundaries, and snow and ice extent. When data from the two channels are compared, an indication of ice/snow melt inception can be discerned. The

IR window channels are used to measure cloud distribution and to determine the temperature of the radiating surface. Data from the three infrared window channels are combined to determine sea surface temperatures.

The AVHRR/2 is composed of five modules that are assembled together to form a single instrument. These modules are:

- Scanner module
- Electronics module
- Radiant cooler
- Optical system
- Baseplate

a. Scanner Module. This module includes the 80-pole hysteresis synchronous motor, the motor housing, and the scan mirror. The scan motor continuously rotates the mirror at 360 rpm to produce a cross-track scanning in orbit. The scan mirror size [20.96 cm (8.25 in) across the minor axis; 29.46 cm (11.6 in) across the major axis] is adequate to fill the field of view of the 20.32 cm (8 in) telescope diameter. The instantaneous field was chosen so that the satellite motion along its orbit would cause successive scan lines to be contiguous at the subpoint.

b. Electronics Module. The electronics module is bolted to the instrument inboard side panel. Electronics functions, including data processing, temperature control, telemetry generation, scan, and motor logic, are contained within this portion of the instrument.

c. Radiant Cooler. The radiant cooler consists of four separate components:

- Cooler housing
- First-stage radiator
- Second-stage radiator (referred to as the patch)
- Cooler cover

The cooler cover shades most of the radiator surface from input radiation from the Earth. The first and second stages have unobstructed views of space, and radiate sufficient energy to bring the patch to its desired operating temperature of 105 K. A proportional heater provides sufficient energy to the patch to keep its temperature from falling below this temperature. Should cooler performance unexpectedly degrade in orbit, it will be possible to restabilize the patch temperature at 107 degrees and continue normal operation.

d. Optical Subsystem. The optical system consists of an a focal 20.3 cm (8 in) aperture telescope combined with secondary optics. This system separates the radiant energy into discrete spectral bands, which are then focused onto their respective field stops. The spectral bands are:

- Channel 1: 0.58 - 0.68 micrometers
- Channel 2: 0.725 - 1.10 micrometers
- Channel 3: 3.55 - 3.93 micrometers
- Channel 4: 10.3 - 11.3 micrometers
- Channel 5: 11.5 - 12.5 micrometers

The instantaneous field of view (IFOV) for all channels is specified to be 1.3 ±0.1 mrad. Polarization effects were minimized to the extent practical by proper orientation of internal optical components. The instrument has been designed such that the IFOV of the five channels can be made coincident within ±0.1 mrad (8 percent). Field of view of the five channels is 1.1 km at the subpoint.

e. Baseplate. The baseplate is the instrument structure upon which all other modules are secured. A cover plate over the electronics modules and the cooler housing serves as a radiator for thermal control.

2. Operating Characteristics

Visible/near IR channels use silicon detectors to measure incident radiation. Both are square, 0.254 cm (0.100 in) on a side. The instrument easily meets the specified 3:1 signal-to-noise (at 0.5 percent albedo) requirement.

The IR channels use detectors cooled to 105 K. The detector chosen for the 3.8 micrometer channel is indium antimonide (InSb), while the 11 micrometer channels use mercury cadmium teluride (HgCdTe). The InSb has a 0.0173 cm (0.0068 in) square active area, and is mounted with the aplanat lens forming a hermetic seal. A noise equivalent temperature difference (NETD) better than 0.12 K (for a 300 K scene) is achieved from this channel. The HgCdTe detector is optimized for best sensitivity between 10.5 and 11.4 micrometers. The detector is 0.0173 cm (0.0068 in) square, and is also bonded to the aplanat. The NETD is better than the specified 0.12 K (for a 300 K scene).

The instrument is designed to operate such that the reference point for detected energy is restored to a preset zero level once each scan while viewing space. The output of the radiometer during the remainder of the scan is equal to the difference in detected energy between space and the radiating surface (Earth). Figure IV-7 is a simplified diagram showing the basic movement of the electronic signals from the detectors to the point where the outputs are sampled at a 40 kHz rate by the satellite data processor MIRP. There are 2.8 samples per cycle, which is well beyond the Nyquist sampling.

The instrument has an internally generated ramp to permit routine validation of the linearity of the instrument electronics. The ramp is produced by an onboard voltage divider, which provides inputs to the A/D converter that will result in outputs from 0 to 1,023 counts. Input voltage intervals were designed to be slightly greater than the equivalent of one output step. In-orbit calibration of the IR channels of the instrument is possible because the instrument output is linear with input energy. During every scan line, the instrument views cold space (near zero radiance), and its housing (approximately 290 K). The housing portion of the instrument has been designed to be a blackbody target to be used in orbit for instrument calibration. Four platinum resistance thermistors (PRTs), whose output values are included in the data stream, are embedded in the housing and monitor the temperature of the target. By determining the instrument output while viewing the known warm target and cold space, it is possible to ascertain the instrument response curve.

3. Radiometric Calibration

The infrared calibration energy sensed by the AVHRR/2 is the difference in the energy received from a calibration blackbody of known temperature and a blackbody of essentially zero radiance. The zero level source is provided by deep space during in-flight calibration, and by a liquid nitrogen-cooled blackbody cavity during calibration in the ground vacuum chamber.

The instrument is specified to have an absolute accuracy of calibration of $\pm 0.5^{\circ}$ throughout the calibration range of each channel. In this context, the words absolute accuracy mean:

> The values determined cluster closely about the true temperature of a blackbody standard reference source, whose calibration is traceable to the National Bureau of Standards.

In the same context, the term precision is defined as:

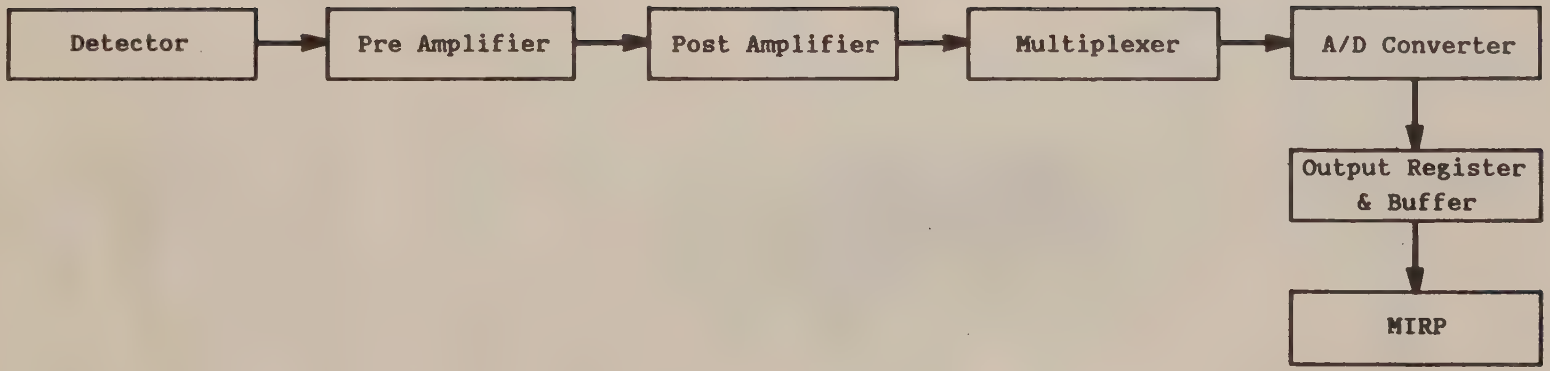

Detector
Pre Amplifier
Post Amplifier
Multiplexer
A/D Converter
Output Register & Buffer
MIRP

Figure IV-7
AVHRR Signal Path From Detectors to MIRP

> A series of measurements whose dispersion (i.e., standard deviation) is small. To be precise, that is repeatable, the value need not be accurate in an absolute sense.

The radiometric calibration procedure on the ground is fairly standard. The instrument is installed in the thermal vacuum chamber such that the cooler will view a liquid helium source, which will bring the detector to its operating range. Two calibration blackbody targets are placed such that they will fill the field of view as the scan mirror passes, first through the area where DC restore occurs, and then through a portion of the scan normally filled by the Earth. Errors and uncertainties in the output of the calibration targets arise from their temperature inaccuracies and their deviation from blackness. Because the calibration signal is equal to the difference in signals from the two targets, the inaccuracies from nonblackness are greatly reduced by making the two targets the same form, and exposing them to the same surround.

The accuracy of the calibration target temperature is limited by measurement errors, control stability, and gradients. The uncertainty of these measurements is about ±0.1°. The error sources and their magnitude are summarized below:

Measurement:	Sensor	±0.05 K
	Instrumentation	±0.05 K
	Control	±0.05 K
Gradient of Target:	Base	±0.10 K
	Honeycomb	±0.06 K
Accuracy (max. errors and uncertainties)		0.32 K
Accuracy assuming "nonblackness"		0.35 - 0.37 K

Instrument outputs are determined as the temperature of the Earth-simulating target is varied from 180 K to 320 K. Separate data sets are obtained as the instrument baseplate temperature is varied over the range expected in orbit.

Targets used for calibration of the AVHRR/2 and HIRS/2 instruments are of identical design and construction. In both cases, they are designed to fill the field of view of the instruments, so that a total end-to-end calibration includes all components from the scan mirror through the infrared detectors, as well as the instrument electronics.

The in-flight calibration is provided by views of the internal blackbody, the housing temperature, and the zero level signal at deep space temperature.

The temperature measurement error in orbit is ±0.05 K from the sensor calibration, and ±0.1 K for instrumentation. When gradient errors and nonblackness factors are added, the total errors become:

Measurement:	Sensor	±0.05 K
	Instrumentation	±0.01 K
Gradients:	Base	±0.08 K
	Honeycomb	±0.08 K
	Total	±0.31 K

With nonblackness errors added, the calibration accuracy becomes ±0.34 - 0.39 K, which is well within the required ±0.5 K.

4. Radiometric and Geometric Precision

To produce meaningful quantitative products from satellite imagery, the sensor data must first be calibrated and Earth-located. Calibration means the interpretation of each data point value as a physical measurement; Earth location means that each data point can be quickly associated with a specific location on the Earth. The accuracy of these two functions is vital to the production of quality satellite data products. Each of these functions, as related to the AVHRR data processing, will be described in this section.

a. Earth Location. Since 1978, NOAA has had an agreement with the U. S. Air Force, Headquarters Space Command (formally NORAD), to track each of its operational polar satellites and provide daily orbit determination and prediction support. Each day, NOAA receives from the Air Force (through the NASA communications system) a set of orbital parameters for each of the NOAA polar satellites. NOAA quality checks this information for consistency, predicts it forward in time, and passes a table of satellite position information to a computer program that generates Earth location data. This program computes an associated Earth location (latitude and longitude coordinates) for a selected subset of AVHRR data samples. This operation is predictive, so that when the AVHRR data arrive at the processing center, these data can be melded with it. As the product processing software accesses the AVHRR data, it can determine the Earth location of any data sample by simple interpolation.

An estimation of the accuracy of the NOAA Earth location must take into account four error contributions. First, the orbit determination performed by the Air Force must provide NOAA with an accurate prediction of the satellite's location in space at any future time. Although the absolute accuracy of this prediction is not known, consistency checks indicate a day-to-day error of usually less than 1 km. Second, the orientation of the spacecraft must be known to determine the appropriate AVHRR pointing angles for any sample. The satellite attitude is maintained by an onboard attitude determination and control system. This system appears to maintain attitude control to less than .1 degree about each axis, which would imply an error of less than 1.5 km at the nadir (straight down). The third contribution to consider would be the mounting angles of the instrument. Careful mounting to meet government specifications makes these errors negligible. And finally, since the data are time tagged by a clock onboard the satellite, this clock may contribute an error. The spacecraft is traveling about 7 km each second, and satellite clocks do drift when compared to GMT. While this error is known to be as much as a half-second, it is measured at the NOAA SOCC. With knowledge of the timing error, the data time tags can be corrected.

With all of these errors taken into account, AVHRR data could be Earth-located to within 2 km. However, in practice, NOAA estimates its accuracy for the entire process to be (on the average) about 5 km.

b. Calibration. AVHRR calibration at NOAA is performed as part of the data preprocessing at Suitland, Maryland. As each scan of Earth data is produced onboard the spacecraft, the instrument also scans an internal target with a known temperature and a view of space. The instrument responses to these two scenes are recorded with the Earth data, and are used by the calibration software to derive calibration coefficients, which, in turn, are appended to the data. These coefficients provide the product processing software with a quick method of converting instrument data into a measure of the received radiance.

The NOAA algorithms use five lines of data to produce one set of coefficients. The mean change, standard deviations (from one set of calibration coefficients to the next), system precision, and preflight estimations of accuracy are given in radiances (mW/Sr m^2 cm^{-1}) in the chart below. A preflight estimation of the sensor accuracies in equivalent temperatures (^{o}C) for a mid-range data value (20 ^{o}C) is given as well.

Channel	Mean change	Standard deviation	Precision (radiance)	Accuracy (radiance)	Accuracy (temp, ^{o}C)
3.7 μm	0.00025	0.00011	0.00014	0.001	0.05
10.8 μm	0.019	0.017	0.162	0.15	0.10
11.8 μm	0.028	0.016	0.191	0.21	0.10

The major portion of operational inaccuracy is caused by the nonlinearity of the 10.8 micrometer and 11.8 micrometer channels. Corrections for these nonlinearities are published by NOAA for each AVHRR instrument when it is launched. Also, all measurements referenced above were derived from prelaunch test data, and do not account for atmospheric effects. Assuming that the instrument components do not deteriorate, these accuracies are maintained for the life of the instrument.

Since the AVHRR does not contain an onboard target for the visible channels, the visible channel response is measured before launch, calibration coefficients are derived, and these remain fixed for the life of the mission.

5. Imaging/Radiometric Applications

Meteorologists have been interested in imagery products in the form of basic cloud pictures since before the launch of TIROS-I. An important function of the AVHRR is to provide imagery capability. The capability of acquiring satellite image data from any land, ocean, or ice-covered region is useful for monitoring surface and atmospheric conditions. Imagery displays are used by meteorologists in observing, analyzing, researching, and forecasting meteorological events. The AVHRR provides imagery at the resolutions desired by meteorology, hydrology, oceanography, agriculture, and other disciplines for which remote sensing has become critically important. Equally important, the AVHRR radiometric data are in digital form. This enables processing of these data on high-speed computers. Users of AVHRR data have come to depend on its unique combination of spatial, spectral, and quantitative data resolution.

One of the uses of the AVHRR is to measure absolute values of sea surface temperature. Single channel measurements are inaccurate, due to attenuation of the radiation as it passes through the atmosphere. In the AVHRR, two channels have been selected to have similar atmospheric absorption characteristics, except that one is attenuated more than the other. Because of the way the channels have been selected, the difference between the two brightness temperatures is proportional to the difference between the brightness temperature of either channel and the sea surface temperature. This gives a direct measure of the atmospheric attenuation, which can be used to correct for the atmospheric effects.

Although the method is fairly simple, the channels have to satisfy several requirements for the method to work. Channels must be mostly transparent, have similar absorption properties with different absorption amounts, and be fairly close to each other in wavelength. As a result of these requirements, spectral regions suitable for the split window are limited. Possibilities exist in the microwave, 10 to 12 micrometers, and

3.7 micrometer window regions. However, surface emissivity varies in the microwave region, and measurements at 3.7 micrometers are affected by reflected solar radiation. This leaves the 10 to 12 micrometer window as the best overall choice. Accuracies of better than ± 0.6 K are routinely achieved in comparisons with fixed and drifting buoys, whose measurements are more reliable than those from all other ships, aside from research vessels.

Even though the two split window channels on the AVHRR provide the primary means for eliminating atmospheric effects, the other channels are essential if the current accuracy levels are to be maintained. The visible channels are used in daylight to detect areas of low uniform stratus that are difficult to detect from 11 and 12 micrometer measurements alone. At nighttime, the unique optical properties at 3.7 micrometer are used in several ways to detect cloud-contaminated measurements. If clouds are not detected, the cloud top temperature is retrieved instead of the sea surface temperature. Methods have also been devised to use both the 3.7 micrometer and visible channels to correct for errors in the atmospheric correction that can result from extensive atmospheric aerosols, such as those caused by the El Chichon eruption. Finally, the measurements in the 10 to 12 micrometer window experience some difficulty in moist atmospheres, at high viewing angles, and with long atmospheric paths. Under these conditions, the atmosphere absorbs too much of the surface radiation to provide the normal error levels. Since the 3.7 micrometer channel is more transparent in moist atmospheres, use of this channel can alleviate some of these problems.

It is important to note that no one pair of channels is likely to provide the best results under all conditions. For example, the 3.7 micrometer window is affected by carbon dioxide to a significant extent, while measurements in the 10 to 12 micrometer range are not. Since carbon dioxide is uniformly mixed in the atmosphere, measurements at 3.7 micrometers vary with atmospheric temperature as well as with atmospheric moisture. This makes 3.7 micrometer measurements more useful in the tropics, where atmospheric moisture is high and temperatures relatively uniform. Measurements in the 10 to 12 micrometer window are better in mid-latitude regions, where the temperature is more variable, and there is less water vapor. Since the best techniques for tropical areas may differ from the best techniques used in other areas, the mix of 3.7 and 10 to 12 micrometer channels on the AVHRR allows specific techniques to be used at different areas. A more restricted instrument would eliminate this possibility.

In addition to sea surface temperature, the AVHRR makes other useful measurements. AVHRR channel 1 (0.55 to 0.68 micrometers) and channel 2 (0.73 to 1.1 micrometers) are useful for monitoring green vegetation, which has a reflectance of about 20 percent in the channel 1 spectral region, but up to 60 percent in the channel 2 part of the spectrum. Other features viewed from space, such as bare ground, water, snow, and clouds, have similar reflectances in the two bands, or a greater reflectance in channel 1 than channel 2. Various mathematical combinations of channels 1 and 2 radiances are correlated with the density and greenness of vegetation.

The combination of small spot size on the AVHRR, and the fact that the 3.7 micrometer channel is extremely sensitive to the hottest object in the field of view, allows the detection of hot spots that are smaller than the field of view. This capability has proven to be a useful tool for the detection of volcanoes and forest fires.

The capabilities of the current instrument will be enhanced by changes that are planned for NOAA K, L, and M. A 1.6 micrometer channel will alternate with the 3.7 micrometer channel. During daylight, where reflected solar radiation contaminates the 3.7 micrometer signal, the 1.6 micrometer channel will be used to distinguish between clouds and snow. In addition, the wavelength of channel 2 will be changed slightly to provide better information about aerosols, and the instrument response will be modified to provide better dynamic resolution at low signal values.

In summary, the AVHRR has provided the capability to measure several parameters of importance to many groups. Among these are sea surface temperature, vegetative index, and forest fires. The present mix of channels is essential if this capability is to be maintained, since each channel is required for one or more of these measurements.

6. Data Availability

The AVHRR data are transmitted simultaneously in real time for direct readout stations, and are recorded on spacecraft digital tape recorders for later transmission to NOAA's CDA stations at Wallops, Virginia, and Gilmore Creek, Alaska. There are four operational modes for transmitting data from the satellite:

- Direct readout to ground stations in APT mode. Coverage is global, resolution is 4 km, spectral coverage is one visible and one IR channel, and panoramic distortion is removed.

- Direct readout to ground stations in HRPT mode. Coverage is global, resolution is 1.1 km, spectral coverage is all five AVHRR channels. (Note: In the HRPT mode, the digital data stream includes TOVS, SEM, DCS, and spacecraft telemetry data.)

- Onboard recording of 4 km resolution data from all five AVHRR channels with GAC are transmitted only to CDA stations.

- Onboard recording of 1.1 km resolution data from all five AVHRR channels with LAC of preselected portions of each orbit are transmitted only to CDA stations. Because of the high data rate, only about 10 percent of the 1.1 km AVHRR observations from any one orbit can be stored on spacecraft recorders. All other 1.1 km AVHRR data are acquired through direct readout, as an HRPT service.

LAC data are obtained by programming the satellite to record observations of a given area. Requests for LAC data may come from NOAA's NWS when there is a major storm or disaster in some part of the world, usually outside the viewing range of GOES. Requests also may come from other U.S. or foreign organizations, government as well as nongovernment. These other organizations are charged a fee for scheduling the observations, reproducing them on tape or as prints, and distributing them.

There are two AVHRR data sources for users:

- Data distributed from NOAA's central processing facility in Suitland, Maryland

- Data distributed from direct readout sites

a. Central Processing. The central processing facility acquires data from both the onboard recorders and HRPT direct readout capabilities through NOAA's two CDA stations. HRPT-transmitted data and stored data are transmitted from the satellites, and are acquired on an 85 ft tracking antenna. The data are recorded at the CDAs, then played back at high data rate via commercial geostationary satellite links. The data are received at the NOAA computer facility in Suitland, Maryland, on a commercial receiving system utilizing a 30 ft antenna. After reception at Suitland, the data are passed to the DACS where they are reconstructed and decommutated. From the DACS the data are passed to the DPSS. Here the imagery is formatted into polar-stereographic quadrants, divided at 10° E., 80° W., 170° W., and 100° E. longitudes, are formatted for both the Northern and Southern Hemispheres. It takes three consecutive orbits to acquire the data necessary for the computer to construct a quadrant mosaic. The processed imagery is written to digital tape. This tape is then manually transported and placed on a minicomputer, where the selected data are transmitted over the GOES WEFAX system at the scheduled times.

The NOAA polar-orbiting satellites make approximately 14 revolutions of the Earth each day. From the AVHRR, the satellite records cloud images of the entire globe in both visible and infrared spectrums. The cloud imagery gathered by the satellites is plotted in digital form, using high-speed computers, to produce mapped data bases. Products produced as imagery from the polar orbiters are:

Stretched Gridded Pass-by-Pass Products. The stretched gridded product is produced in near real time to provide the users a quick look at the latest recorded imagery. The coverage is a single strip from pole to pole, and covers about 25 degrees longitude. The product displays imagery from any one of the five AVHRR channels in the GAC data stream.

Grids, coastlines, and labeling information are melded with the imagery to aid the users in recognizing cloud locations. The picture elements are adjusted to remove the foreshortening near the horizons caused by the curvature of the Earth, and the scanning geometry of the radiometer. The adjustment is accomplished through sample replication; the result is a quasiequal area image.

The stretched gridded product is used for general meteorological applications, such as the determination of cloud coverage, cloud types, and systematic patterns of cloudiness. It is used by the Joint Ice Center in their analysis of ice fields, the Central Intelligence Agency, the Department of Agriculture and the NWS.

Hemispheric Polar-Stereographic Mosaics. From a combined 24-hour set of AVHRR GAC data observed by the polar-orbiting satellite, six polar-stereographic mosaics are made for the Northern and Southern Hemispheres. Mosaics are available for the visible, IR day, and IR night, with a resolution of 15 km at the Equator and 30 km at the poles. These photographic displays are produced at about 0400 Z for daytime and nighttime observations.

In order to transmit the data to the users as soon as possible, sectors of the mapped mosaics are extracted and disseminated via the weather facsimile (WEFAX) network. Anyone with a WEFAX receiver and within the signal range of the geostationary satellites can receive the mapped sectors.

The polar mosaics are used for general meteorological applications, such as the determination of cloud coverage, cloud types, and systematic patterns of cloudiness. The mosaics are archived in digital form on computer-compatible tapes for retrospective processing and for research.

Mercator Mosaics. The Mercator mosaics are made from 24 hours of stored AVHRR GAC observations as viewed from the polar-orbiting satellite. These mosaics cover from 40° S. to 40° N. latitude, comprising a total 360° of longitude in two sections.

Selected sectors of the Mercator mosaics are extracted before the 24-hour map is completed, and disseminated to users via WEFAX.

The Mercator mosaics are used for general meteorological applications, such as determination of cloud coverage, cloud types, and systematic patterns of cloudiness.

Local Area Cover Images. The AVHRR senses in the visible and infrared spectrum with a resolution of about 1 km at satellite subpoint (directly below the satellite). For a selected portion of each orbit, photographic displays are produced from the high-resolution data available from the LAC capability of the polar orbiters.

Users acquire LAC images by subscribing to an electronic distribution system known as GOES-Tap. The GOES-Tap signal originates from the NESDIS Central Data Distribution Facility (CDDF) in Suitland, Maryland. Users receive input signals over phone lines, and can display the information on an image display device. GOES-Tap is jointly managed by the NWS and NESDIS.

LAC data have been used in monitoring oceanographic, hydrologic, and land-related phenomena. In oceanography, transportation interests chart ship courses based on location of ocean currents and eddy circulations. The positions of ocean features are derived from enhanced HRPT/LAC infrared satellite images. Enhanced imagery also depicts areas of upwelling that mark potential fishing grounds, particularly along the U.S. west coast. Image composites are used to create sea surface temperature charts, which are useful in Coast Guard search and rescue operations, commercial fishing operations, lake freeze-up determinations, oil drilling operations, and whale migration monitoring.

In hydrology, LAC data are useful for deriving flood potential and mapping flood extent. Specially enhanced LAC images have been used to monitor water and lake quality, and to help local and state governments better manage water resources. Using the unusual spectral characteristics of infrared channel 3 (3.55 to 3.93 micrometers), LAC images have been used to detect fires, volcanic eruptions, and urban development. The

Federal Aviation Administration (FAA), the NWS, and the U.S. Forestry Service have supported development of operational techniques for volcano monitoring and forest fire detection. The USDA has worked with NESDIS to develop a regional and global vegetation monitoring capability (Vegetation Index) using LAC data.

Seven-Day Minimum Brightness Composite. The 7-day minimum brightness composite product is produced from selected sectors of 7 consecutive days of the polar stereographic mapped mosaics. By saving only the minimum brightness response of each mapped location, this process filters out the bright clouds that do not remain at the same location for the 7 days. This filtering leaves a "clear" image of the background surface area for all but those areas with persistent cloudiness.

This product is used in locating permanent snow fields and ice fields in the polar regions. It is used in the preparation of the Northern Hemisphere snow and ice charts. By comparing the composite with other meteorological data, the analyst is able to separate the snow fields and ice fields background from clouds.

Earth Radiation Budget. It is in this application where the unique capabilities of the AVHRR are especially needed. The global radiation budget is analyzed from the polar-orbiting satellite AVHRR data. Measurements of daytime and nighttime outgoing longwave flux, and incoming available and absorbed solar radiation, are made using average infrared and visible radiances from 50 km regions. Using the AVHRR channel 5 (infrared "window"), measurements of outgoing longwave flux are calculated for both day and night. The albedo obtained from channel 1 (visible) are used to calculate available and absorbed solar radiation during the day. These measurements are combined with time, Earth location, and angular measurements of satellite and solar altitude to form an initial data base for analysis. Radiation budget parameters from 14 orbits (one complete day) are composited to increase signal-to-noise ratio, and to derive daytime and nighttime longwave flux, each from 12 hours of IR data, and absorbed solar energy from the difference between the solar constant and measurements of reflected radiation obtained from the visible data.

Radiation budget measurements are mapped into 2.5° latitude-longitude fields, and stored on a monthly archive file. A photographic display of the radiation budget fields is produced daily for quality control purposes, and the monthly file is archived to tape at the end of each month. An experimental set of monthly mean contour charts is also produced.

Radiation budget estimates are used by climatologists to study climate changes. The global radiation budget measurements are important to long-range weather forecasting. Also, the Climate Analysis Center of the NWS uses the albedo measurements to make precipitation estimates in agricultural areas of the world not covered by the GOES satellites.

Sea Surface Temperatures. In addition to the standard products described above, AVHRR data are used to determine sea surface temperatures on both a local and global basis. Of particular value are the locations of the interfaces between cold and warm water masses. These interfaces have different significance in different applications.

Off the coast of the western United States, the warm/cold sea water interface occurs around upwellings from the sea bottom. These upwellings bring nutrients to the surface, and thus are the feeding grounds for both warm- and cold-water species of fish. Given the location of these interfaces, which the AVHRR images produce, commercial and sport-fishing fleets are able to locate promising fishing areas before leaving port.

In the Atlantic coastal area, these interfaces are used to locate the Gulf Stream. Commercial shipping interests utilize this knowledge to route ships to make use of the northward flowing Gulf Stream; this saves time and fuel when operating up and down the Atlantic coast.

b. Direct Readout. As described in previous sections, the AVHRR instrument on the polar-orbiting satellites is continuously collecting observations and transmitting information, regardless of whether the satellite is or is not within the range of CDA stations in the United States. Continuous transmissions enable any nation to receive satellite images or products in time to incorporate them into their national or regional forecast programs. Aboard ship, on islands, in the polar regions, and even in some developed countries such as Brazil and Australia, the direct broadcast services provide not only the most expedient, but sometimes the only source of weather information.

Direct Sounder Broadcasts (DSB) of TOVS data included in the HRPT data stream are covered briefly at the end of this section. TOVS technical information is discussed in chapter V. This section addresses only how HRPT, APT, and to some extent DSB services make data available by direct broadcast.

HRPT data are received by any station with the proper receiving equipment within range of the spacecraft . The signal is transmitted continuously, on S-band (1698.0 - 1707.0 MHz), at full resolution (1.1 km). These data can be intercepted by any organization or individual without any financial, political, or legal obligations to the U.S. Government. Furthermore, there is no obligation on the part of the receiving organization to report the existence of its station to the United States. Of course, the cost of building or buying HRPT receiving equipment--$0.5 million to over $1.0 million in most cases--is borne by the receiving agency. (Current worldwide investments in HRPT receiving equipment are estimated at slightly less than $100 million, to which facilities and recurring staffing costs must be added.)

This freedom of access to the AVHRR data, through the HRPT service, has led to the establishment of at least 100 HRPT stations in over 44 countries (as of March 1985). While approximately 30 of these stations are operated and maintained by U.S. Government and military agencies (more than two-thirds by the DOD), most are operated by non-U.S. entities--government, military, academic, and even radio amateurs overseas. Primary users overseas are government meteorological agencies, and those with hydrologic or oceanographic forecasting responsibilities. Other key operators include national space agencies and academic institutions.

More often than not, a single HRPT receiving station relays the data to a large user community for operational or research support. In the United States, nearly all the AVHRR data collected by NOAA are acquired via HRPT direct readout. In the United Kingdom, the HRPT station at Lasharm Airfield relays the data to the Meteorological Service in Bracknell, which in turn sends it to over 40 other meteorological offices within the country. Several HRPT receiving stations also archive the data and make it available to other agencies. HRPT data copied at Lannion, France, for example, in addition to being used operationally, is also provided to the Food and Agricultural Organization in Rome for locust control in Northern Africa, and to the U.S. Navy in New London, Connecticut, for oceanographic studies of the Mediterranean Sea.

Obviously, hundreds, perhaps thousands, of individual and organizational needs are served by the relatively few HRPT stations now in existence. The number of HRPT stations is expected to grow substantially in the near future, as technological developments lead to lower cost HRPT receiving and processing equipment. Even if the number of HRPT stations did not increase, however, the number of users of data from this service will increase as more organizations become aware of the availability and utility of high-resolution products provided by the AVHRR/HRPT data.

c. Automatic Picture Transmission Services. The APT services are also derived from the operation of the AVHRR. More than 1,000 stations capable of receiving APT data currently exist. The data are provided as a time-multiplexed output of two selected channels from the AVHRR, with appropriate calibrations and telemetry data. After digital processing, during which panoramic distortion is removed, the processor on the spacecraft converts the data to a low bit rate analog signal for transmission at a resolution (4 km) image on VHF (137.50 or 127.62 MHz). During daylight, one visible and one infrared channel of the AVHRR is normally sent; at night, two IR channels are transmitted. [The APT services have been provided by polar-orbiting satellites since 1963, but it has only been since the introduction of the VHRR (predecessor to the AVHRR) that more than one channel of data could be transmitted to APT stations.]

Data availability is one of the major reasons for the proliferation of APT stations; the data are continuously available, in "raw" or unprocessed form, on VHF. There are no "strings" attached to receiving and using the data. There are other reasons as well: utility, flexibility, low cost, and portability. The data have great utility for most of the developing countries, and to forecasters and scientists on ships, islands, and in the polar regions, where APT extends the area that can be observed beyond radar range, often into areas where no other type of observations are available. Under ideal conditions, an APT receiving station can receive data from a radius of 6,500 km.

APT data offer flexibility; they can be displayed as an analog or digital output, sectorized, enhanced, or colored for greater "readability." As for cost, most government agencies can afford an APT ground receiving station. Commercial systems with tailored processing capabilities may cost as much as $800 million, but less sophisticated stations can be purchased for between $30 and $60 million. Amateur stations have been built for less than $200. In terms of portability, "suitcase" type systems have been built and transported into wilderness areas, or used aboard small recreational vessels. One mountain-climbing expedition hopes to be able to backpack a system to the 15,000-ft level of Mt. Everest, on the back of a yak, to support the ascent team. The system would provide the capability for real-time weather observing in areas essentially void of observing stations, and where lives will depend as much, or more, on actual, rather than forecasted, weather. It is this type of "data availability" that has made the APT system so valuable to so many people and organizations.

d. Direct Sounder Broadcast Service. A third direct readout service, the DSB service, although not provided by the AVHRR, depends in large measure on the HRPT data stream to convey information. Changes in the way AVHRR data are transmitted would also affect provision of the DSB services to at least 20 stations in 16 countries today, and to at least three other countries in the very near future.

The DSB service is derived from the operation of the TOVS instrument, and enables atmospheric temperature and moisture data to be acquired and used in numerical weather prediction and long-range weather forecasting efforts. It also provides ozone measurements. Any HRPT station can receive and remove that part of the signal used to generate soundings, although few stations have the technical capability to do this today. However, efforts have been underway for several years to correct this situation, making this extremely valuable data more accessible and useful to other meteorological agencies.

V. RELATIVE ANALYSES AND USES OF DMSP AND POES SOUNDERS

A. DMSP SOUNDING INSTRUMENTS

A tabular technical comparison of the DMSP sounding instrument (SSM/T) and the NOAA/POES sounding instrument (TOVS) is provided in table V-1. The following discussion compares the respective sounding systems in greater detail.

1. Microwave Temperature Sounder (SSM/T)

Knowledge of the temperature distribution of the atmosphere on a global scale is a key factor in the prediction of various weather parameters by meteorologists. Although some such profile information is currently available from radiosonde, rocketsonde, and infrared atmospheric sounding systems, each of these systems has its obvious limitations. The multichannel passive microwave radiometer system (SSM/T) has been developed for use on the DMSP to gather such temperature distribution information on a global basis.

a. Spectral and Spatial Sensing Characteristics. Profiling of the atmosphere from sea level to an altitude of 30 km has resulted in the selection of seven channels ranging in frequency from 50.5 GHz to 59.4 GHz as shown in table V-1. A requirement for a maximum calibration uncertainty of 1 K and maximum noise equivalent temperature difference (NETD) for the various channels of 0.4 to 0.6 K has established the electrical performance requirements of the SSM/T sensor system. Weight, power, and size limitations of 25 lb, 18 W, and 8 by 12 by 16 in, respectively, restrict the physical characteristics of the sensor (tables V-2 and V-3).

b. Sounding Precision. This instrument provides approximately 15,000 temperature soundings per day to the AFGWC upper-air data base. Atmospheric temperatures (+2.5 K) are retrieved for pressure levels 1,000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, and 10 mbar. In addition, 14 thicknesses between these levels, and the temperature and pressure of the tropopause, are provided (table V-4).

c. Sounding Applications. Soundings produced from SSM/T data consist of atmospheric temperatures for 15 pressure levels, corresponding layer thicknesses, and the temperature and pressure of the tropopause. Height contours are derived at AFGWC by summing individual retrieved layer heights and adding a forecast 1,000 mbar height.

The vertical temperature profiles provided by SSM/T data supplement conventional data in creating the Upper Air Data Base (UADB) at AFGWC. The UADB provides the input for automated

Table V-1

Sounder Technical Comparison

Characteristic	SSM/T	TOVS		
		MSU	SSU	HIRS/2
Spectral Channels	7 channels 50-60 GHz region	4 channels 50 GHz region	3 channels 15 μm region	20 channels 4 & 15 μm region
Data Distribution	Surface - 10 mb (30 km)	Surface - 50 mb	15.5 mb-1.5 mb 25 km - 50 km	Surface - 10 mb
Field of View	186 m at nadir 12° IFOV	109 km at nadir 7.5° IFOV	147 km at nadir 10° IFOV	17 km at nadir 1.4° IFOV
Optics Size	N/A	N/A	5 cm (2 in)	15 cm (6 in)
Signal to Noise (NE∧T)	Variable by channel: 0.4-0.7 K	Uniform by channel 0.3 K	Variable by channel* 0.3-->1.75	Variable by channel* 0.001-.175
Dynamic Range	4-330 K	4-320 K	0-250 K	0-340 K depending on channel
Digitization	12 bit	12 bit	12 bit	13 bit
Calibration	Space/Internal blackbody target	Space/Internal blackbody target	Space/Internal blackbody target	Space/Internal blackbody target (2)
Line Rate	32 s/line	25.6 s/line	32 s/line	6.4 s/line
Scan Field of View	±36° from nadir 7 steps	±47.4° from nadir, 11 steps /9.4° ea.	± 40° from nadir 8 steps/8.0° ea.	±49.5° from nadir 56 steps/ 1.8° ea.
Weight	25 lb	73 lb	43 lb	73 lb (33 kg)
Power	14 W	32 W	16 W	23 W
Design Life	3 yr (4 yr goal)	2 yr	2 yr	2 yr
Cost	$2.5 M	$1.5 M	Furnished by U.K.	$2.25 M

* Depends upon selected bandpass, which limits energy availability. Noise equivalent radiance, milliwatts/m^2-ster-cm^{-1}

TABLE V-2
SSM/T CHANNEL PARAMETER REQUIREMENTS

Channel	Peaking Height (km)	Frequency (GHz)	Bandwidth (MHz)	NETD
1	0	50.5	400	0.6
2	2	53.2	400	0.4
3	6	54.35	400	0.4
4	10	54.9	400	0.4
5	30	58.4	115	0.5
6	16	58.825	400	0.4
7	22	59.4	250	0.4

TABLE V-3

SSM/T KEY SCAN PARAMETERS

Scan Type	Cross-Track
Cross-Track Positions	7
Calibration Positions	2-Cosmic Background and 300 K Source
Total Cross-Track Scan	± 36°
Total Scan Period	32 Sec
Dwell Time (cross-track and calibration positions)	2.7 Sec

TABLE V-4
SSM/T DATA SPECIFICATIONS

Environmental Parameters Sensed/Derived

–Measures microwave radiation emitted by the atmosphere at seven frequencies in the 50-60 GHz molecular oxygen (O_2) line

–Spectral channels 50.5, 53.2, 54.35, 57.9, 58.4, 58.825, 59.4 GHz

–Derived geophysical parameters are temperature values from the surface to 30 km

Data Accuracy

–RMS temperature error 2.5 K

Data Coverage

–Daily global coverage with gaps below about 60° latitude

–Horizontal swath width 861 NM

Data Resolution

–Horizontal resolution of seven scene stations ranges from 93 NM at nadir to 160 NM edge of scan

–Vertical resolution, seven independent pieces of data between 0 to 30 km

–One scan every 32 sec (approx. 250 km in track)

Other Comments

–Flown on F-7 and all but one future spacecraft analysis models such as the High-Resolution Analysis System (HIRAS) and the Point Analysis Model. The output from HIRAS initializes all of the numerical prediction models used by AFGWC to produce global and regional forecasts. These numerical analyses and forecasts support global Air Force, Army, and Navy strategic and tactical operations, along with other specialized applications (tables IV-3 through IV-4C).

d. Data Availability. Same as SSM/I (chapter IV).

2. Microwave Water Vapor Sounder (SSM/T-2)

The SSM/T-2 is an Aerojet Electrosystems Corporation follow-on to the current SSM/T microwave temperature sounder, which will include channels at 91.5 and 150 GHz, and in the 183 GHz water vapor resonance line to provide a moisture profiling capability. Water vapor mass would be retrieved in four layers: surface to 850 mbar, 850 to 500 mbar, and 500 to 0 mbar. Total integrated water mass would also be determined. Successful retrieval of this profile information requires a calibration error of 1.5 K, and an NETD not exceeding approximately 1.0 K.

The proposed system uses the same modular construction as that of the SSM/T, as well as such other features as a stepped cross-track scan, a shrouded closed-path calibration network, and passive thermal control. The mechanically scanned parabolical reflector antenna system provides a planar scan by mechanically rotating the reflector surface; this allows the antenna feed system to remain fixed. The antenna beam is step-scanned across the Earth at a fixed, programmed rate, then rapidly rotated, first to a warm calibration reference, then to a cold calibration reference, before the scanning sequence is repeated. The radiometric temperatures of the calibration reference provide absolute calibration points, so that the absolute antenna temperatures can be determined. The calibration paths are closed and characterized by low losses, so that the equivalent antenna input temperature during calibration can be accurately determined.

The SSM/T-2 would scan 28 positions cross-track. The antenna beam width of 3 degrees at the subsatellite point provides a horizontal resolution of about 40 km. This is significantly better than the 174 km resolution of the SSM/T. If operated with a collocated SSM/I instrument, improved water vapor profile calculations can be obtained using a first guess of integrated water vapor and cloud water content from the SSM/I (table V-5).

a. Spectral and Spatial Sensing Characteristics: The five channels will be 91, 150, 183.311 ±1, 183.311 ±3, and 183.311 ±7 GHz.

TABLE V-5

SSM/T-2 DATA SPECIFICATIONS

Environmental Parameters Sensed/Derived

—Atmospheric radiance in 91.5 GHz, 150 GHz and 183 GHz bands

—Parameters derived: Water vapor profile in four layers

Data Accuracy

—TBD

Data Coverage

—±40.5° from nadir (±750 km)

Data Resolution

—Horizontal resolution 40 km

—Scan time 8 sec (60 km along track)

Other Comments

	System Characteristics
Radiometer Type	Total power
Frequencies (GHz)	91.5, 150, 183 ±1, 183 ±3, 183 ±7, 183 GHz
Spatial Resolution (km)	46.5 x 46.5 @ nadir
Scan Angle (degrees)	±40.5, 28 views
Swath Width (km)	1596
Scan Increment	3°
Antenna Bandwidth	3.0° at 183 GHz
Thermal Sensitivity (K)	0.6 to 0.8
Calibration Accuracy (K)	±1.5
Weight	29 lb
Size	TBD
Power	30W
Data Rate (bits/sec)	324
Uncompensated Momentum	0.02 in –lb/sec

This system is comparable to the SSM/T in physical characteristics with four times the resolution and scan rate and nearly equivalent thermal sensitivity and calibration accuracy.

b. Sounding Precision

Resolution: Horizontal - 16 x 10 km
Vertical - four layers:
Surface - 850 mbar
850 - 700 mbar
700 - 500 mbar
500 - 10 mbar

Sensor Response: Delta T rms = 1-2 K

c. Sounding Application. See tables IV-3 through IV-4C.

SSM/T and SSM/T-2 Measurements. These data, if of sufficient resolution and accuracy, would provide a three-dimensional view of the upper-air temperature (both) and water vapor content (SSM/T-2 only). The temperature field enables the forecaster to analyze for atmospheric stability. When stability is compared with water vapor content, the forecaster can determine the following meteorological conditions:

- Types of clouds that will form or occur, if any. This is especially useful in forecasting thunderstorm development, intensity, and coverage.
- Potential for icing.
- Location of weather systems in areas of high water vapor content, but few or no clouds. This may provide the first clue for the development of new storm systems.
- Potential for fog/stratus formation.
- Enhancement of existing cloud analysis models (e.g., RTNEPH), which rely on computer processing and interpretation of satellite imagery from the OLS.

Operational Uses of SSM/T and SSM/T-2 Measurements. The information from these measurements would be briefed to appropriate personnel to make decisions on:

- The best route of flight, area/target, arrival/alternate stations to avoid or reduce the threat of hazards (i.e., thunderstorms and icing)
- The best operational area/target and arrival/alternate stations, based on potential for fog and stratus formation
- Employment decisions for E/O weapons; support to intelligence collection systems; support to ICBM forces (reentry forecasts)

d. Data Availability. Same as SSM/I (chapter IV).

3. Infrared Temperature and Water Vapor Sounder (SSH-2)

The infrared multispectral sounder measures infrared radiation emitted by the Earth's surface and atmosphere in 16 spectral bands. These have been selected to provide radiance measurements, which may be inverted using physical radiative transfer models and data processing techniques to yield profiles of atmospheric temperature and water vapor content. Six of the bands are in the 15 micrometer CO_2 absorption band, and eight are distributed over the pure rotational water vapor absorption band near 20 micrometers. The two remaining bands are at 3.7 micrometers and the 12 micrometer window region, and measure ozone and surface temperature, respectively (table V-6).

The SSH-2 scans 25 steps across the subsatellite track. During the 1 second dwell at each scan station, a complete set of multichannel radiance measurements is made, from which atmospheric temperature and water vapor profiles can be calculated. After completion of the 25-step Earth scan, the SSH-2 slews to positions that allow calibration looks at cold space and at an internal radiance source. It then returns to the starting point for another Earth scan. The complete cross-track line scan and calibrating cycle takes 32 seconds. The SSH-2 has a 2.7 degree field of view and scans 50 degrees across track.

Incoming radiance is directed into SSH-2 collecting optics Cassegrain mirror system. The radiance signal is chopped at a frequency of 16 Hz and subdivided spectrally into three wide band channels by the use of two dichroic optical elements. The wide band channels are designated channel E (650 to 900 cm^{-1}), channel F (350 to 550 cm^{-1}), and channel W (2,425 to 2,900 cm^{-1}). In the E and F channels, the radiation is subdivided by the use of seven narrow-band filters in the F filter wheel, and eight narrow-band channels in the E filter wheel.

The water vapor retrieval accuracies obtained with the SSH-2 have been unacceptably poor. Also, operation of the instrument is limited to clear temperature profile measurements under nearly all weather conditions. For these reasons, there are questions regarding whether any future DMSP launches will carry the SSH-2.

a. Spectral and Spatial Sensing Characteristics. The SSH-2 is a scanning infrared spectroradiometer that has the capability of measuring radiance in 16 spectral bands from 2,700 cm^{-1} to 350 cm^{-1}. The SSH-2 was designed to provide soundings of temperature and humidity for vertical and slant paths lying under and to each side of the subsatellite track.

TABLE V-6
SSH-2 DATA SPECIFICATIONS

Environmental Parameters Sensed/Derived

–Measures infrared radiation emitted by atmosphere and Earth's surface at six frequencies in the 15 micron CO_2 absorption band, at eight frequencies in the 20-30 micron water vapor absorption band, and at two window frequencies near 10 and 3.7 microns

–Spectral channels:

CO_2:	3.4, 13.7, 14.1, 14.4, 14.8, 15.0 microns
H_2O:	12.5, 18.7, 20.1, 24.5, 22.7, 23.9, 25.2, 28.3 microns
Window:	11.1, 3.7 microns

–Derived parameters include vertical temperature and moisture profiles from the surface to 30 km

Data Accuracy

–RMS temperature error = ±2.5-3K

–No useful moisture profiles have been retrieved

–Navy uses one channel to compute total water vapor in a column

Data Coverage

–Daily global coverage with gaps below about 55° latitude

–Horizontal swath width 1102 NM

Data Resolution

–Cross-track resolution of 25 scene stations ranges from 30 NM at nadir to 60 NM at edge of scan (±48°)

–Along-track resolution 112 NM, one scan per 32 sec

–Vertical resolution, six independent temperatures between surface and 30 km

Other Comments

–Only one SSH-2 remains to be flown

The along-track spacing is 112 nmi, and the cross-track spacing is 31.5 nmi at nadir increasing to 85 nmi at the edge of the scan.

b. Sounding Precision. The SSH-2 is designed to accurately measure narrow-band atmospheric radiance for all operating conditions and for operating temperatures between 5 and 25 °C. The dynamic range of the instrument has been set up to maintain the accuracy measurement throughout this operating range for atmospheric temperatures from 0 to 320 K.

c. Sounding Applications. Same as SSM/T (see tables IV-3 through IV-4C).

d. Data Availability. Same as SSM/I (chapter IV).

B. TIROS OPERATIONAL VERTICAL SOUNDER (TOVS)

1. Instrument Descriptions - Characteristics

The TIROS Operational Vertical Sounder (TOVS) system consists of three instruments, each with unique characteristics, which are combined to produce atmospheric temperature profiles. These instruments will be discussed separately.

a. High-Resolution Infrared Radiation Sounder (HIRS/2). The HIRS/2 utilizes a 15 cm (6 in) diameter optical system to gather emitted energy from the Earth's atmosphere. The instantaneous field-of-view of all the channels is stepped across the satellite's track by use of a rotating mirror. This cross-track scan, combined with the satellite's motion in orbit, provides coverage of a major portion of the Earth's surface.

The energy received by the telescope is separated by a dichroic beam-splitter into longwave (above 6.4 micrometers) and shortwave (below 6.4 micrometers) energy, which is controlled by field and passed through bandpass filters and relay optics to the detectors. In the shortwave path, a second dichroic beam-splitter transmits the visible channel to its detector. Essential parameters of the instrument are shown in table V-7. Primary system components include:

- Scan system
- Optics, including filter wheel
- Radiant cooler and detectors
- Electronics and data handling
- Mechanics

Instrument Operation/Scan System. In orbit, the instrument output is locked to the spacecraft clock. The scan mirror synchronizes its stepping to this clock, starting a new scan line in conjunction with the other TOVS components, upon receipt of a major frame pulse from the spacecraft. The mirror steps from its initial or home position in 55 1.8° steps (56 data points) over its 99° swath (measured from the spacecraft). When data acquisition is complete, at the last position (56), the mirror rapidly returns to the first (home) position, and repeats the Earth-scan pattern. Each scan line requires 6.4 s. Synchronization with both of the other instruments occurs every 128 s (every 20 scan lines).

Table V-7
HIRS/2 System Parameters

Parameter	Value
Calibration	Stable blackbodies (2) and space background
Cross-track scan	±49.5° (+1,120 km)
Scan time	6.4 seconds
Number of steps	56
Optical field of view (FOV)	1.25°
Step angle	1.8°
Step time	100 milliseconds
Ground instantaneous field of view (IFOV) -- (nadir)	17.4 km diameter
Ground IFOV (end of scan)	58.5 km cross-track by 29.9 km along-track
Distance between IFOVs	42 km along-track
Data rate	2,880 bits/second

The instrument can be commanded to enter a calibration mode automatically every 256 s. Upon receipt of the calibrate command, the instrument enters the calibrate mode. Starting from the beginning of a scan line, the mirror rapidly slews (equivalent to the time for eight scan elements) to a space view where it stops for the length of time necessary to complete one line (equivalent to 48 scan elements). All channels of the instrument are sampled during this period. The mirror is then moved to a position where it views a cold calibration target. Data are taken from the equivalent of 56 scan steps, at which time the scan mirror is stepped to view the internal warm target. After another 56 samples, the mirror continues its motion to the start of scan (home) position, where it begins normal Earth scan. The total calibration sequence is equivalent in time to three scan lines. No Earth data are obtained during this period.

Optical System. The HIRS/2 optical system has been based largely on the design used for the HIRS/1, flown on the Nimbus research satellite. Small changes to the longwave design have been instituted, primarily to eliminate vignetting, and to ensure that a minimum of energy from beyond the field of view reaches the detectors. The optical path (port) to the cooler has been kept as small as possible to reduce the heat-loading effects. The effective field of view of the instrument has been defined by the field stops.

The first dichroic transmits the longwave and reflects the shortwave and visible channels. Therefore, two field stops define the field of view; one is for longwave channels, the other for short. Immediately behind the field stops, the bandpass-defining filters are grouped on a wheel that rotates in such a manner that the energy reaching the detectors is defined by each filter in turn. The shortwave filters are located along the circumference of an outer radius, while the longwave defines an inner circumference. A chopper tooth is rigidly attached to the wheel and rotates with it; signal integration is confined to the time interval while viewing an optical filter. Length of the filter (and, therefore, the length of integration) has been chosen to provide an adequate signal-to-noise ratio.

The relay lens system is used to focus the received energy on the detectors. The goal of the design was to reduce vignetting and provide uniform illumination across the field.

Cooled detectors are used for all IR channels, because of their high sensitivity and short response time. The detectors are maintained at their operating temperature (105 K) by a thermostatically controlled passive radiant cooler.

Spectral Channel Characteristics. The HIRS/2 instrument makes measurements in 20 spectral regions, the specifications for which are given in table V-8. The individual bandpass filters are positioned on the filter wheel in a manner consistent with the requirement to ensure registration with the longwave and shortwave window channels. Longwave to shortwave registration is achieved by adjusting the two detectors relative to each other. Response outside of bands is held to the minimum level consistent with state-of-the-art filter design.

Radiant Cooler and Detectors. The HIRS/2 instrument uses two solid-state IR detectors, which operate most efficiently near 105 K. As is the case for the AVHRR, the longwave detector is mercury-cadmium-teluride (HgCdTe), the shortwave is indium antimonide (InSb). A silicon detector operating at ambient temperatures is used for the visible channel.

The radiant cooler is functionally the same as that used for the AVHRR. Modifications to the cooler have been limited to those necessary to interface with the HIRS/2 optical system. Tests have shown that the cooler can reach an operating temperature of about 97 K, if it were permitted to run uncontrolled. This provides an adequate reserve margin to ensure continuous operation at the 105 K control point.

To ensure that outgassing products do not condense on the cooler during the initial time in orbit, the cooler will be heated to 30 °C for approximately 2 weeks following launch. The same heaters are also available to drive off contaminants in the event cooler performance degrades during the 2-year lifetime. It has not been found necessary to use these heaters in orbit, since no cooler degradation has been noted that would cause the system to lose control.

Scan System. The mirror scan system for the HIRS/2 has been designed so that during Earth-scan stepping, the mirror steps 1.8 degrees to each new position with minimum overshoot, and settles to within 0.1 degrees in 35 ms. A mirror position encoder provides a positive indication of the scan position of the mirror.

Electronics and Data Handling. The instrument output consists of digitally converted data levels for each spectral interval at sufficient dynamic range and quantizing resolution to allow extraction of all radiometric information. The range of signal from each channel is adjusted to conform with the range of input temperature expected in that spectral interval. Each channel signal will be offset to make full use of the 13-bit digital system.

In the TIP data stream, the HIRS data will be provided as a serial bit stream with no break or fill zeros to match the

Table V-8
HIRS/2I Spectral Requirements

Channel	Channel Frequency	Micro-meter cm^{-1}	Half Power Bandwidth cm^{-1}	Anticipated Max. Scene Temperature (K)	Specified NEN*	Design Goal
1	669	14.95	3	280	3.00	0.75
2	680	14.71	10	265	0.67	0.25
3	690	14.49	12	240	0.50	0.25
4	703	14.22	16	250	0.31	0.20
5	716	13.97	16	265	0.21	0.20
6	733	13.64	16	280	0.24	0.20
7	749	13.35	16	290	0.20	0.20
8	900	11.11	35	330	0.10	0.10
9	1,030	9.71	25	270	0.15	0.15
10	797	12.55	16	290	0.20	0.15
11	1,365	7.33	40	275	0.20	0.20
12	1,488	6.72	80	260	0.19	0.10
13	2,190	4.57	23	300	0.006	0.002
14	2,210	4.52	23	290	0.003	0.002
15	2,240	4.46	23	280	0.004	0.002
16	2,270	4.40	23	260	0.002	0.002
17	2,420	4.13	28	330	0.002	0.002
18	2,515	4.00	35	340	0.002	0.002
19	2,660	3.76	100	340	0.001	0.001
20	14,500	0.69	1,000	100% (Albedo)	0.10% (Albedo)	-

* NEN in mW/m^2 St cm^{-1}

16-bit TIP word pairs. All 20 channels of radiometric data will be accommodated in the 36-word (18 word pairs), 288-bit allocation in each TIP minor frame. All telemetry necessary to process the data is included in the instrument output data stream, while housekeeping telemetry is included within the spacecraft telemetry slots.

b. Stratospheric Sounding Unit (SSU). The SSU has been supplied by the United Kingdom Meteorological Office. It employs a selective absorption technique to make measurements in three channels. Basic characteristics are shown in table V-9.

The SSU makes use of the pressure modulation technique to measure radiation emitted from carbon dioxide at the top of the Earth's atmosphere. A cell of CO_2 gas in the instrument's optical path has its pressure changed (at about a 40 Hz rate) in a cyclic manner. The spectral characteristics of the channel, and, therefore, the height of the weighting function, are then determined by the pressure in the cell during the period of integration. By using three cells filled at different pressures, weighting functions peaking at three different heights can be obtained. The primary objective of the instrument is to obtain data from which stratospheric (25 to 50 km) temperature profiles can be determined. This instrument is used in conjunction with the HIRS/2 and MSU to determine temperature profiles from the surface to the 50 km level.

Instrument Operation. The single primary telescope with its 10 degrees IFOV is step-scanned perpendicular to the subpoint track. Each scan line is composed of eight individual 4.0 s steps, and requires a total of 32 s, including mirror retrace. The 147 km subsatellite point resolution produces an underlap between lines of approximately 62 km at nadir.

The SSU uncooled pyroelectric detectors integrate the radiance in each channel for 3.6 s during each step. The integrated output signal level is sampled eight times during this period; quantization is to 12-bit precision. Telemetry data are inserted into the TIP data stream, together with the radiance data, making the data output rate up to 30 TIP word-pairs per second.

Scan System. A single 8 cm diameter scan mirror serves the three instrument channels. To reduce any possible bias errors, separation of the optical axes of the three channels is kept to a minimum. The mirror and the various apertures have been dimensioned to allow a clear path for rays up to 3 degrees outside the nominal field of view. A fiberglass sun shield has been included to prevent reflected sunlight from contaminating the measurements.

Optics and Electronics. The SSU detector is a flake of triglycine sulphate (TGS). The flake is attached to the end of a

Table V-9
SSU Characteristics

Channel Number	Central Wave No. cm^{-1}	Cell Pressure mbar	Pressure of Weighting Function Peak mbar	km
1	668	100	15	29
2	668	35	5	37
3	668	10	1.5	45

conical gold-plated nickel light pipe. The 1.1 mm diameter exit aperture of the pipe defines the illuminated area on the flake, and the 6 mm diameter input end of the pipe, with the objective lens, defines the field of view.

The three detectors are mounted in a common block, which also provides an integral housing for the preamplifiers. In-orbit calibration checks are confined to two points near the extreme of the radiometer's input range. It is important, therefore, that the response of each channel be linear. The electronics were designed with 0.1 percent linearity as a requirement. Monitoring of the operating frequencies of the PMCs, which depend on their internal pressures, provides the only direct means of verifying that the weighting functions are unchanged.

An interference filter is used to reject radiation at more than 50 wave numbers from the center of the Q-branch of the 15 micrometer CO_2 band. This filter is mounted between the absorption cell and the field lens.

Pressure Modulated Cell (PMC). The PMC consists of a sealed CO_2 cell and a means of modulating it. The cell provides a 1 cm CO_2 path with germanium optics coated to provide high transmission at 15 micrometers. The cell is mounted to a cylinder within which is mounted a piston. The available modulation for a peak-to-peak piston amplitude of 3 mm is about 28 percent.

The mean pressure in the cell is about seven times the pressure at the peak of the weighting function. Fluctuations in depth of modulation would be reflected in radiometer sensitivity changes. To ensure stable operation in orbit, the amplitude of piston motion is kept constant by an electronic servo system.

In-Flight Calibration. In synchronism with the HIRS/2, once every 256 seconds (eight scans) the SSU, when operating in auto calibrate, enters a mode where the instrument first looks at space and then an internal blackbody target. Since incoming radiation is modulated with respect to the mean temperature of the PMC CO_2, the space view provides a larger signal than any atmospheric scene. The internal blackbody near 15 °C will provide a minimum level signal close to the opposite extreme of the temperature range.

c. Microwave Sounding Unit (MSU). The MSU, an instrument built by the Jet Propulsion Laboratory of the California Institute of Technology, is a four-channel Dicke radiometer, making passive measurements in four regions of the 5.5 mm oxygen region. The frequencies are shown in table V-10, which lists the instrument parameters.

The instrument has two scanning reflector antenna systems, orthomode transducers, four Dicke superheterodyne receivers, a data programmer, and power supplies.

The antennas scan 47.4 degrees on either side of nadir, in 11 steps. The beam width of the antennas is 7.5 degrees (half-power point), resulting in a ground resolution at the subpoint of 109 km. Microwave energy received by each antenna is separated into vertical and horizontal polarization components by an orthomode transducer. Each of the four resulting signals is fed to one of the radiometer channels. The incoming noise temperature is modulated at a 1 kHz rate by a Dicke switch, so that a constant comparison is made between the ambient temperature reference load and the incoming signal. A two-point calibration is accomplished by a cold space view and a housing view, once each scan period. Each radiometer channel is sensitive to inputs originating from temperatures ranging from 0 to 350 K. Each radiometer channel gain is then approximately 35 mV/K; digitization is to 12-bit precision. Primary system components include scan system, electronics, and data unit.

Instrument Operation. In orbit, this instrument uses the spacecraft clock system to maintain scan synchronism. The rotating reflectors are synchronized to the clock, starting a new scan line in conjunction with the other TOVS instruments upon receipt of a major frame pulse. The reflector steps from its initial home position in ten 9.45 degree steps (11 Earth views) over its 102 degree swath (measured from the satellite). From the last Earth view position, the reflector rapidly moves four steps to view space and 10 additional steps to view the housing, then returns to the home position to begin another scan line. Each scan line requires 25.6 seconds, so that synchronization with the other two TOVS instruments occurs every 128 seconds (five scan lines).

Table V-10
MSU Instrument Parameters

Characteristics	Value CH 1	 CH 2	 CH 3	 CH 4	Tolerance
Frequency (GHz)	50.3	53.74	54.96	57.05	±20 MHz
RF bandwidth (MHz)	220	220	220	220	Maximum
NEΔT K	0.3	0.3	0.3	0.3	Maximum
Antenna beam* Efficiency Specification	90 %	90%	90%	90%	
Dynamic range K	0-350	0-350	0-350	0-350	

Calibration	Hot reference body and space background each scan cycle
Cross-track scan angle	±47.35°
Scan time	25.6 s.
Number of steps	11
Step angle	9.47°
Step time	1.84 s.
Angular resolution	7.5° (3 db)
Data rate	320 bps

* 95 percent generally achieved

Unlike the HIRS/2 and SSU, there is no special calibrate sequence that interrupts normal scanning. At each data-taking position, one engineering word (voltage), two temperature sensors, four instrument outputs, and the scan position angle are digitized for inclusion in the assigned TIP slots. The analog-to-digital converter is a 12-bit unit, and four additional bits are added for telemetry, yielding a 16-bit word for the TIP.

Scan System. The scan system consists of the antenna subsystem, antenna drive, and position-measuring subsystem and structural support.

The antenna system consists of two rotating reflectors with fixed corrugated horns. The reflectors are attached to bearings that are rotated by highly accurate pulley drives, which are attached to a 90 degree stepper motor and a set of miniature drive belts.

The antenna positions are monitored by a potentiometer and an encoder. The encoder is a disk type, generating angular position with a resolution of 256 counts (gray code) per revolution.

The antenna support structure is made of aluminum, and has a microwave blackbody calibration load where the antenna dwells for 1.9 seconds during each scan period (25.6 s). The calibration load consists of parallel rows of knife-edge material made by casting an iron-filled epoxy onto an aluminum backing plate. These essentially isothermal targets, with embedded temperature monitors, provide one of two calibration points for each antenna. The second calibration point is the cold space view.

Electronics System. The instrument electronics consists of three chassis--the Radio Frequency (RF), IF/video, and data. These three components are mechanically connected by support brackets, radiator plates, and the antenna subsystem baseplate.

Data Unit. The data unit consists of a multiplexer and an analog-to-digital (A/D) converter. The A/D has 12-bit precision with a relative accuracy of ±0.05 percent. The multiplexer accepts the analog data, monitors signals from the four channels, and commutates them in sequence for the A/D converter. The sequencing and synchronizing signals for the multiplexer, the A/D converter, and the scan system are provided by a digital programmer, which in turn interfaces with the spacecraft clock and synchronization signals. The programmer also provides formatting and buffering functions between the instrument and the spacecraft TIP.

2. Radiometric Calibration

a. HIRS/2 Calibration. The infrared calibration energy sensed by the HIRS/2 is the difference in the energy received from a calibration blackbody of known temperature and a blackbody of essentially zero existence. The zero level source is provided by deep space during in-flight calibration, and by a liquid nitrogen-cooled blackbody cavity during calibration in the ground vacuum chamber. The instrument is specified to have an absolute accuracy of calibration of ±0.5 K throughout the calibration range of each channel.

The radiometric calibration procedure on the ground is fairly standard. The instrument is installed in the thermal vacuum chamber, such that the cooler will view a liquid helium source, which will bring the detector to its operating range. Two calibration blackbody targets are placed such that they will fill the field of view as the scan mirror passes, first through the area where DC restore occurs, and then through a portion of the scan normally filled by the Earth. Errors and uncertainties in the output of the calibration targets arise from their temperature inaccuracies and their deviation from blackness. Because the calibration signal is equal to the difference in signals from the two targets, the inaccuracies from nonblackness are greatly reduced by making the two targets the same form and exposing them to the same surroundings.

The accuracy of the calibration target temperature is limited by measurement errors, control stability, and gradients. The uncertainty of these measurements is about ±0.1 K. The error sources and their magnitude are summarized below:

Measurement:	Sensor	±0.05 K
	Instrumentation	±0.05 K
	Control	±0.05 K
Gradient of Target:	Base	±0.10 K
	Honeycomb	±0.06 K
Accuracy (max. of errors and uncertainties)		0.32 K
Accuracy assuming "nonblackness"		0.35-0.37 K

Instrument outputs are determined as the temperature of the Earth-simulating target is varied from 180 K to 320 K. Separate data sets are obtained as the instrument baseplate temperature is varied over the range expected in orbit.

Targets used for calibration of the AVHRR/2 and HIRS/2 instruments are of identical design and construction. In both cases they are designed to fill the field of view of the instruments, so that a total end to end calibration includes all components from the scan mirror through the infrared detectors, as well as the instrument electronics.

The in-flight calibration is provided by views of the two internal blackbodies, one controlled near 270 K, the other near 300 K within the instrument housing, and of the zero level signal at deep space temperature.

The temperature measurement error in orbit is ±0.05 K from the sensor calibration and ±0.1 K for instrumentation. When gradient errors and nonblackness factors are added, the total errors become:

Measurement:	Sensor	±0.05 K
	Instrumentation	±0.01 K
Gradients:	Base	±0.08 K
	Honeycomb	±0.08 K
	Total	±0.31 K

With nonblackness errors added, the calibration accuracy becomes ±0.34 to 0.39 K, which is well within the required ±0.5 K.

b. SSU Calibration. The calibration process for the SSU involves exposing the radiometer to an extended blackbody source that has been calibrated against a primary or secondary standard of one of the national laboratories. This procedure establishes a relationship between the output of the radiometer and the measured radiance of the blackbody source. The SSU was extensively calibrated by the United Kingdom's Meteorological Office. This process also established the instrument's stability, linearity of response, and sensitivity in output digital counts. All calibrations were done in a thermal/vacuum environment, with the instrument exposed to a baseplate operating temperature of 25 °C ±10 °C. Instrument response is determined for a range of measured radiance inputs over this temperature range. Frequency variations of the cells are also monitored over the temperature range to determine stability.

During normal operation in orbit, calibration of the SSU instrument is performed once every 256 seconds. The scan sequence format for the SSU allows the instrument to view space and an internal blackbody target to provide a two-point check of instrument response. The SSU calibration line contains four dwell periods of space data, followed by four dwell periods of internal target data. Each dwell period contains eight radiometric data samples per channel. The accumulation of these samples over a 4 second dwell period produces a linear relationship between output samples (counts) and time (seconds). The slope of this line (defined as a RAMP), in counts per second, is computed using a least squares equation. An average of four RAMP values from the space view, and an average of four RAMP values obtained while viewing the internal target, are used in the calculation of the calibration coefficients.

The temperature of the internal target can be determined from the thermistor data samples obtained during the calibration sequence. Precision platinum resistance thermistors (PRT) are used to provide a precise measurement of the internal target temperature. This measured blackbody temperature is converted to a radiance value for each channel. Channel gains are then calculated, using the radiance values for space, and the internal blackbody, respectively, and the average RAMP value for the space and the internal target views. From this, intercepts are calculated. The intercepts for each of the channels are monitored on a continuous basis for quality and event sequence evaluation.

c. MSU Calibration. Advantage has been taken of the specific scanning technique used by the MSU to develop a unique and very accurate method of calibration. The method consists of adding two extra steps to the antenna step-scan, one of the steps allowing the antenna to view deep space, and the other allowing a view of a calibration target. Space provides a cold (near 3 K) calibration point, and the target, maintained near instrument-ambient temperature, provides a warm (near 250 K) calibration point. Since most of the temperature viewed by the instrument during its operation over the Earth ranges between 150 and 280 K, these two calibration points allow interpolation for the reduction of the measurements.

Since both calibration sources are external to the complete instrument, the calibration points are directly relatable to the data points, without the necessity for intermediate calibrations or computations. This is possible because a complete cycle of the scan mechanism, which includes 11 data points and the two calibration points, is completed every 25.6 seconds. During this short time, no significant change in the temperature of the antennas, and the antenna to radiometer wave guides, is expected during normal operations; thus, the reradiation component from the antenna and wave guide elements can be assumed constant for each intercalibration period. The radiometers, being of the Dicke switched type, and also being essentially at a constant temperature, can be assumed to be stable during each intercalibration period.

From the foregoing, it can be concluded that emphasis in the calibrations has to be on the following three major areas:

- Antenna pattern characteristics
- Calibration target characteristics
- System temperature transfer function

Two types of tests and calibrations are performed with the completely assembled instrument. The first type is performed under "laboratory" environment, and consists of viewing various types of calibration targets of known characteristics to establish overall systems level transfer functions. These tests include measurements with the Precision Antenna Calibration Source (PACS), and performance verification tests during spacecraft integration.

The second type is performed in a vacuum environment during thermal-vacuum testing, and consists of viewing various calibrated targets. The following overall operating characteristics of each radiometer by itself are determined:

- Input Voltage Standing Wave Ratio (VSWR)
- Temperature transfer function
- Sensitivity (T_{rms})
- Stability
- Center frequency and bandwidth

Input VSWR. The input VSWR of the radiometers across their individual passbands is determined by utilizing a swept reflectometer technique as used for the RF components.

Temperature Transfer Function. The dynamic transfer characteristic of a linear radiometer can be expressed in the form:

Equation (1)

$$T_A = A(t) + B(t)\ E_0$$

where T_A = input temperature, K
$A(t)$ = radiometric zero, K
$B(t)$ = radiometer gain scale factor, K/V
E_0 = radiometer output, V
t = physical temperature of radiometer, K

The coefficients A(t) and B(t) are dependent on the ambient temperature of the instrument. The accuracy of the temperature transfer function will be tested during the thermal-vacuum tests, where the radiometer output will be compared with the physical temperature of an external target. The target temperature will be varied between 100 K and 350 K while the instrument temperature is varied between 280 K and 320 K. If the thermal-vacuum tests indicate any nonlinearity in the instrument response, a small correction term, quadratic in E_0, can be added to Equation (1).

Complete calibrations on all flight models are performed at six instrument temperatures within the appropriate ranges, and on the protoflight at eight temperatures.

The objective of the thermal-vacuum chamber calibrations is to determine quantitatively how the instrument relates the signals received when the antennas view the Earth in positions 0 through 10 to the calibration signals received in the sky, and calibration target positions (positions 11 and 12).

For this purpose, the calibration equipment has to be such that the RF field surrounding the instrument is controlled and known. In this manner, the antenna temperatures in the Earth- and sky-viewing positions are known accurately, and allow computation of the antenna temperature delivered by the onboard calibration target. This latter quantity then can be related to the physical temperature and other constant properties of the calibration target. Once the calibration target characteristics are determined, the normal sequence of events consists of using the calibration target and the sky inputs for computing the value of the signals received in the Earth-viewing positions.

To relate the calibration target properties to the simulated sky and Earth inputs, it is essential that considerable care be exercised in the design and construction of the equipment used in performing the tests. In particular, shields have to be provided around the microwave absorber sources simulating the Earth and the sky. Otherwise, the entire vacuum chamber, which behaves as a blackbody of unknown temperature due to multiple reflections on the shroud, chamber walls, and the instrument itself, would introduce unacceptable uncertainties into the calibrations. The temperature distribution of the calibration sources must also be carefully controlled for uniformity, both over the area of the sources and in time. An objective of ±1 °C for each type of variation was used in the designs to keep the temperature monitoring requirements to a reasonable size. Techniques such as "bifilar" cooling/ heating coils on the back of the target plates and manifolding, as well as good thermal insulation and tight control loops, were used. The sky calibration source is always maintained at or near LN_2 temperatures, and the Earth source is variable from LN_2 temperatures of 77 K to about 350 K.

Antenna Patterns. Radiation patterns are measured for all MSU antennas over a minimum dynamic range of 60 dB. The amplitude accuracy will be ±3 percent in dB (e.g., 0.3 dB at the -10 dB point and 1.8 dB at the -60 dB point), and the angular resolution is ±0.3 degrees. All measurements are made in the far field of the antenna assembly.

All pattern cuts are great circles passing through the center of the antenna beam, and all angles are measured between the great circle and the antenna rotation axis. Gain measurements are taken at 0.5 degree intervals.

The MSU antennas and the antenna range transmitter antennas are linearly polarized. The relative polarization angles between the test and transmitter antennas are measured at the center of the beams, and are determined to an accuracy of at least ±1 degree at all polarizations except the 90 degree polarization, where the accuracy required is ±0.2 degrees.

3. Sounding Precision

A primary function of the NOAA POES is to measure the vertical temperature and humidity structure of the atmosphere. The temperature and humidity profiles are globally required for the continuous observation of the state of the atmosphere, and are utilized as input for circulation models used in weather forecasting. The two polar-orbiting spacecraft provide complete global coverage of vertical temperature and moisture profile every 6 hours.

The profiles (soundings) are produced from data available from the TOVS, which is a three-instrument system on the POES. The three TOVS instruments are: the HIRS/2, the MSU, and the SSU. These instruments sense atmospheric temperatures in the 15 and 4.5 micrometer region, as well as the 53 GHz spectral regions; atmospheric water vapor in three channels centered in the 7.3 micrometer region; and the Earth's surface temperature in three infrared window channels. Table V-11 summarizes the characteristics and purpose of the radiance observations provided by the various spectral channels of each instrument.

Infrared technology has long been used for deriving measurements of atmospheric temperature. Improvements in infrared detectors, and solid-state devices for microwave radiometry, opened the way for more sophisticated means for indirect sounding. In deriving accurate temperature soundings, clouds represented a major limitation, since infrared detectors are severely affected by the presence of clouds. Microwave observations are largely uninhibited by cloud droplets. Thus, in the presence of clouds, opaque to the infrared channel, soundings can be made from observations in the microwave spectral region. Therefore, the MSU is used to derive soundings primarily in cloud-contaminated areas.

Indirect soundings in the lower atmosphere (troposphere) are improved if the measurements extend through the stratosphere. This is because the upwelling radiation is integrated throughout the entire atmosphere. The SSU provides radiance measurements in the stratosphere.

Table V-11
Data Products From TOVS

---

1. HIRS
    - (a) Temperatures from the surface up to 30 km
    - (b) Water vapor profiles for three layers
    - (c) Total ozone
    - (d) Cloud information - cloud top temperature, cloud coverage
    - (e) Geopotential heights
    - (f) Tropopause data - temperature and pressure
2. MSU
    - (a) Temperatures in cloud-covered fields of view
    - (b) Temperatures in clear areas above clouds
    - (c) Geopotential heights
3. SSU

    Stratospheric temperatures - from 30-65 km

The accuracy of satellite atmospheric sounding is measured by comparison with radiosonde data. For mandatory pressure levels in the atmosphere, layer-mean temperature accuracies are: surface to 850 mbar, ±2.5 K; 850 mbar to tropopause, ±2.25 K. Layer-precipitable water accuracy is 30 percent. Clear radiance measurements are within ±2 percent.

4. Sounding Applications

The accuracy of the numerical model predictions used for weather forecasting is dependent on the quality, quantity, and timeliness of the observational data. Weather models analyze the state of the atmosphere, and predict the change in its behavior.

To analyze and forecast large-scale weather systems, the horizontal and vertical distribution of temperature, moisture, wind, and pressure must be observed globally over a period of time. Conventional radiosondes have traditionally been used to provide the required observations. But radiosondes leave many unanswered questions about the behavior of the atmosphere. A critical "data void" exists over the vast oceanic areas.

The POES sounders provide global observations of temperature and humidity for synoptic scale analysis. The two polar-orbiting spacecraft provide complete global coverage every 6 hours. Secondary products produced from the POES sounder data are total ozone profiles and cloud cover. The ozone and cloud cover products are used by researchers to study changes in the Earth's climate.

The prime user of the atmospheric profiles produced from the POES sounder data is the NWS's National Meteorological Center (NMC). Within the NMC, POES soundings provide essential observations for the numerical weather prediction models, upper-air (stratosphere) analysis, and climate research.

Soundings data are used as input to the NMC's numerical weather predicition in the 12 to 72 hour time frames. The POES are placed into deliberate orbits to provide optimum coverage to suit the data input needs of the NMC's analysis cycles. The satellite soundings are of great value to the numerical weather prediction models, because the satellite soundings fill many of the data gaps not covered by conventional observing systems. These data gaps occur in many remote areas of the world. The data gaps include the oceans, deserts, and polar regions, where it is extremely difficult to obtain atmospheric observations. Numerical weather forecasts require as detailed as possible analysis of current atmospheric conditions over the entire Earth's atmosphere.

Of particular importance to the NMC are satellite soundings over the Northeast Pacific Ocean. This area breeds many of the meteorologically significant weather features that affect storms entering the United States. The satellite passes that cover this area are a major element in the POES program for setting its mission objective. Without the POES sounding data, NMC forecast models would have little or no new information to provide the type of detailed analysis needed for numerical weather predictions. The POES sounder data are used to fill in much of the horizontal detail not resolved by the relatively wide separation of the conventional (radiosonde) observing stations. The details of atmospheric temperature and moisture are crucial for the proper delineation of storm intensities, frontal positions, and location of the upper level jet streams.

Another important use of the POES sounder data is for upper-air (35 to 55 km) analysis. The TOVS provides measurements from the surface to approximately 65 km. The SSU instrument is used primarily for deriving stratospheric temperatures in the upper atmosphere. The stratospheric data are used for many applications. These include monitoring the Earth's atmosphere for long-term changes (global cooling), measuring the quantity and motion of aerosols and other atmospheric constituents, and determining atmospheric density and winds.

Another application of the POES sounders is the production of daily total ozone concentration maps on a global basis. The ozone profiles available from the TOVS are used daily by climatologists and aviation forecasters.

In summary, the POES sounders are an important operational asset because they provide the latest observations from data-sparse areas of the globe. These observations are used for numerical weather forecasts by both national and international scientists to help derive more accurate short-term forecasts. The POES sounders also support research and developmental activities in the area of global climate studies, and other long-range science programs and goals.

5. Data Availability

The two polar-orbiting satellites provide some 16,000 soundings per day. Each of the NOAA series satellites, orbiting the Earth every 100 minutes, produces roughly 600 soundings per orbit. A display of the density of observations for a given 24-hour period in the Northern Hemisphere is shown in figure V-1.

The raw radiance data from the three POES sounders are converted into operational products consisting of layer-mean temperatures for standard pressure levels, layer-precipitable water amounts, total ozone, cloud cover, and clear radiance values for each of the three instruments of TOVS.

The NWS uses the soundings by accessing computer files for input into the current day's weather analysis and forecast models. The soundings are archived by the Satellite Data Services Division of the NESDIS. A portion of the sounding products are formatted into the World Meteorological Organization (WMO) code for transmission over the GTS network. By agreement with the British Meteorological Office, Earth-located calibrated radiances and coefficients, which are used to derive soundings, are provided by a low data rate line.

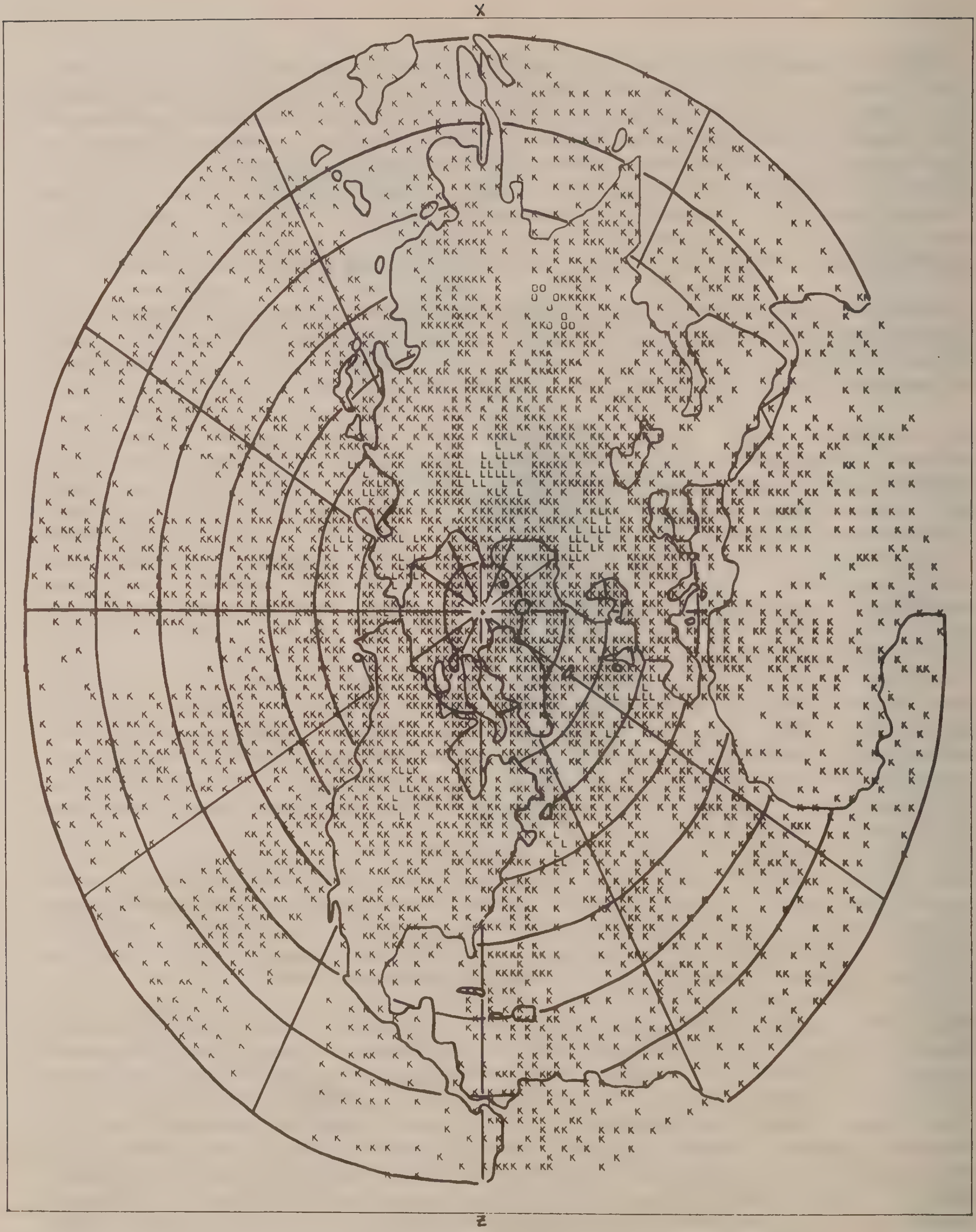


Figure V-1
Northern Hemisphere 24-Hour POES Sounding Density
(two-satellite coverage)

6. Channel Selection

a. General Criteria. The first and most important requirement for the TOVS instrument is that it sound the atmosphere for temperatures from the surface to as high in the stratosphere as possible. The accuracy of retrieved temperature profiles in the lower atmosphere depends directly on accurate stratospheric temperature measurements. This is because a temperature retrieval for a given level depends upon the ability to account, as closely as possible, for the radiation emitted from the entire atmosphere above that level. Thus, the selection of the spectral intervals (channels) on TOVS, used for temperature sounding, must account for radiation through the entire extent of the atmosphere, not just in the troposphere, where most storms and weather occur.

In the channel selection process, the vertical portion of the atmosphere from which the radiation arises for a given channel must be known. This information is provided by the derivative of the atmospheric transmittance function associated with each channel. This derivative is known as the "weighting function." The weighting functions are generally bell-shaped curves, and the location of the maximum value on the bell is referred to as the "peak" of the weighting function. As a first approximation, the selection of channels is such that the peaks of the associated weighting functions are distributed uniformly throughout the effective vertical extent of the atmosphere. The effective top of the atmosphere for NOAA purposes is around 65 km.

The initial selection process must be refined to take into account the statistical correlations that exist between temperatures in different atmospheric layers. Because some of the temperature retrieval information can be obtained from the statistical properties of the atmosphere, not all layers need to be weighted equally to obtain equal retrieval accuracy. Consequently, statistical information in the form of covariance matrices was used in deciding just how the peaks of the weighting functions should be distributed to arrive at the optimum set of channels.

The covariance matrices also were used to determine the optimum number of channels. Because of measurement noise in the radiances, and the broad half-widths of the weighting functions, there is a fixed number of channels that can be used to advantage. After that number is exceeded, the channels become redundant, in that additional channels provide no new information.

b. HIRS Longwave and SSU Channel Selection. Because infrared technology was originally the most highly developed, and because of historical reasons, the infrared region has been the primary spectral region for temperature and moisture sounding. Within the infrared region the 15 micrometer band of CO_2 was the first and the principal band used for temperature sounding for two reasons: it has the maximum available energy, and the most uniform temperature sensitivity relative to detector noise at terrestrial temperatures. This longwave temperature sounding capability is provided by HIRS/2I channels 1 through 7 of table V-7. However, these channels are limited to the height interval from the surface to 30 km, because of spectral bandpass and energy throughput limitations of the interference filters. The purpose of the SSU instrument, with its pressure-modulated CO_2 gass cells, is to extend the maximum height from 30 to 65 km. Thus, the first seven HIRS/2I longwave channels of table V-8, plus the three SSU channels of table V-9, provide the optimum set of channels for temperature sounding in the 15 micrometer band of CO_2.

c. HIRS Shortwave Channel Selection. The shortwave infrared temperature sounding channels on the HIRS/2I instrument (channels 13 through 17 in table V-8) are in the 4.3 micrometer band of CO_2 and the 4.5 micrometer band of N_2O. They have the advantage of having a much higher temperature dependence than any other temperature sounding channels. This arises from the fact that the Planck radiance changes much more rapidly with a given change in temperature than in the other usable spectral regions. For example, at 700 cm^{-1}, the Planck radiance changes by a factor of 5.5 in going from 200 K to 300 K, while for the same range of temperatures, the Planck radiance changes by a factor of 215 at 2,240 cm^{-1}. Consequently, the shortwave channels are more sensitive to vertical and horizontal temperature changes in the warmer regions of the atmosphere. (In the colder regions, the energy is closer to the detector noise level, and, hence, the shortwave channels are not very useful there.) This temperature sensitivity manifests itself in the effective weighting functions (i.e., the usual weighting functions multiplied by the derivative of the Planck function with respect to temperature) in the form of much narrower effective weighting functions, which yield better vertical resolution. Other advantages of the shortwave infrared channels are that they are less sensitive to clouds because of their low sensitivity to cold temperatures, and they have less water vapor contamination than do the longwave channels.

In summary, channels 13 through 17 on HIRS were selected to improve the temperature accuracy in the middle and lower troposphere. The particular distribution and number of channels were determined as in the previous discussion. However, channel 17 requires additional explanation.

Channel 17 has mainly nitrogen continuum absorption, and a weighting function that peaks at the surface. It has only weak water vapor absorption and a positive dependence of transmittance on temperature. Positive dependence means that channel 17 becomes increasingly transparent with increasing temperature, which is not true of the other shortwave channels. In fact, the longwave channels have a negative dependence of transmittance on temperature. Consequently, channel 17 yields better surface temperature information than do any of the longwave channels. Furthermore, when this channel is used in conjunction with the other channels (longwave and shortwave), its contrasting characteristics yield surface information not otherwise available.

d. Microwave Channel Selection. For purposes of temperature sounding, radiation in the 50 to 70 GHz region of molecular oxygen absorption offers two advantages over the infrared regions, which are dominated by carbon dioxide absorption. They are the transparency of microwave radiation in the presence of cloud particles, and nearly monochromatic detection resulting in channels with very narrow bandwidths. The first practical microwave radiometers built for satellite use were the Nimbus-E Microwave Spectrometer (NEMS) and the Scanning Microwave Spectrometer (SCAMS) flown on the Nimbus spacecraft.

The MSU instrument is a direct descendant of those two instruments, and was intended solely as a supplementary and supporting instrument to the HIRS and SSU instruments. It is important to keep this in mind, in view of the fact that present plans are to develop the Advanced Microwave Sounding Unit (AMSU) as the primary temperature sounding instrument, supplemented by a modified version of the infrared HIRS instrument. The reason for the switch in emphasis is that the AMSU is an all-weather radiometer, almost insensitive to clouds, whose channels nearly duplicate the present combined longwave HIRS and SSU channels. This has been made possible by advances in microwave technology.

The four channels on the MSU are listed in table V-10, and their roles originally were envisioned as follows. Channel 1, a window channel, was to be used for determining surface effects and precipitation. Channel 2, sounding the midtropospheric levels, was to provide the bulk of the MSU temperature sounding information. Channel 3, sounding the mid-latitudinal tropopause level, was considered useful as an indicator of overall lapse rate. Channel 4, a lower stratospheric sounding channel, was included because of promising results from the SCAMS as an indicator of the tropical and subtropical tropopause.

While these original aims were incorporated in the TOVS software development, a different emphasis has been placed on the MSU data from the beginning. The idea of having complete dependence of the retrieval system upon MSU data in the troposphere in areas too cloudy for the inclusion of HIRS data was introduced. Following a series of modifications to the original data-reduction scheme, the importance of the microwave-only retrieval in certain areas has been demonstrated, but the full realization of this potential must await the availability of the AMSU.

e. Water Vapor Channel Selection. Moisture is retrieved both for its own sake and because of its influence in the lower troposphere on the atmospheric transmittance functions used in temperature sounding and in the window channels. Water vapor sufficiently abundant to be retrieved by nadir sounding methods is found only in the lowest 10 km of the atmosphere.

It was realized early in the moisture channel selection process that, while the electromagnetic spectrum is rich in regions of strong water vapor absorption, essentially only three channels are sufficiently independent of one another to be useful. Thus, precipitable water amounts can be obtained in only three layers in the lowest 10 km, using three channels. Channels 10, 11, and 12 of table V-8 are the three water vapor channels on HIRS/2I. Because the atmospheric distribution of water vapor changes so dramatically with season and latitude, and even daily, it is impossible to determine an optimum set of water vapor channels.

The 6.3 micrometer band was chosen because it is a very broad band with strong H_2O absorption lines, and regions that are quite free from absorption by other gases. All three water vapor channels originally were selected in this band, but the most transparent channel was found to be at a restrahlen frequency over desert and other hard surfaces. Consequently, the most transparent channel was changed to 797 cm^{-1} for HIRS/2I (table V-8). This new selection was motivated by the fact that the new channel 10 is sufficiently close in frequency to channel 8, and the pair can be used in the split window technique for obtaining surface parameters.

Even though channel 8 is considered to be a window channel, it has enough water vapor absorption to be used as a water vapor channel, if necessary. However, channel 8 is still somewhat less absorbing than channel 10.

f. Ozone Channel Selection. Originally, the ozone channel was included on the HIRS instrument solely for the purpose of determining total ozone amount, so that it could be used in calculating the contribution of the 14 micrometer O_3 band absorption to the transmittance functions of the longwave temperature sounding channels. More recently, total ozone amount also has been retrieved, as an operational product, from a combination of the ozone channel and some of the temperature sounding channels. Thermal channels are used because of the strong correlation between ozone concentration and temperature.

g. Window Channel Selection. The HIRS/2I has four window channels and the MSU has one. These are channels 8, 18, 19, and 20 in table V-8, and channel 1 in table V-10, respectively. Broadly speaking, the purpose of these five window channels is to detect and eliminate nuisance parameters, such as cloud and surface effects. More specifically, the selection of each window channel frequency is dictated by its particular function.

For instance, since channel 2 of the MSU is affected by surface emissivity, a microwave window channel (channel 1) was selected that has an even greater sensitivity to surface emissivity (and consequently less sensitivity to atmospheric temperature), so that it could be used to determine the emissivity parameter. Once this parameter is known (along with the surface temperature), its influence is removed from channel 2.

Since the microwave sounding channels are affected by precipitation, and since the window channel again is affected most strongly, it is used to detect precipitation contamination of the brightness temperatures. When this occurs, no temperature retrieval is attempted.

The infrared window channels play roles analogous to that of the microwave window channel. Since many of both the longwave and shortwave sounding channels are influenced by surface radiation, the window channels are used to eliminate, or account for, this influence. In particular, channel 8 is used to determine the surface temperature. On the other hand, most of the shortwave channels also are affected by reflected solar radiation. Channels 18 and 19 are used to provide simultaneous radiance data at contrasting frequencies to remove the reflected solar component from the radiances of the sounding channels.

Finally, most of the infrared radiance measurements are strongly attenuated by clouds. Since window channels are even more sensitive to clouds, they, along with the visible channel (channel 20 in table V-8), are used to detect the presence of clouds in the field of view. However, the window channels are used only indirectly in the removal of cloud effects; the microwave channels are the key to the successful removal of cloud contamination from the infrared radiances.

VI. RELATIVE ANALYSES AND USES OF OTHER SENSORS

Current state of the art for solar/ionospheric capabilities is covered in the Air Force System Commands Technical Report ESD-TR84-198, WX-2000 Technical Report, Volume I, 20 September 1984, pages 4-24 to 4-43, which lists needs, capabilities, and deficiencies. Table VI-1 shows where these data can be or are being collected. DMSP improvements include SSUV, SSI/ES, and SSM. These instruments will be used in new models under development. Their importance and how they will improve current state of the art is covered in sections A through H, below.

Sections I through L treat the supplementary sensors and subsystems carried by the NOAA polar-orbiting environmental satellites for monitoring the solar and near-Earth environment for radiation and atmospheric ozone profiles in response to Public Law 95-95. Also covered are the systems for collecting environmental data and locating aircraft and ships in distress.

A. PRECIPITATING CHARGED PARTICLE SPECTROMETER (SSJ/4)

The purpose of the precipitating charged particle spectrometer (SSJ/4) instrument is to measure the flux and energy spectrum of electrons and ions that precipitate from the Earth's magnetosphere and cause ionization and visible aurora in the E-region of the ionosphere at high latitudes. In addition to its direct use as an indicator of regions undergoing intense auroral activity, data from the SSJ/4 and its predecessors have been used to develop models of the variation of the location of the equatorward boundary of the aurora as a function of geomagnetic index and as input to computer codes that calculate the Hall and Pederson conductivities of the auroral E-region as functions of latitude, local time, season, and geomagnetic activity.

The SSJ/4 measures the flux of electrons and ions in 20 energy channels in the range from 30 eV to 30 KeV. This is accomplished using a set of four cylindrical curved plate electrostatic analyzers arranged in two pairs. Each analyzer consists of three basic components: an aperturing system, a set of two concentric cylindrical curve plates, and a pair of channeltron detectors. The aperturing system collimates the incoming particles, which are then acted upon by an electric field such that particles entering the space between the plates are accelerated toward the inner plate. If the incoming particle's energy is such that the centrifugal force experienced by the particle, as its trajectory is bent by the electrical field, equals the electrical field force, the particle passes along the gap between plates, impacts the

TABLE VI-1
SOLAR/IONOSPHERIC DATA SOURCES

	Could Be Done By Satellites	DMSP	Ground	Other Satellite
Galactic				
Cosmic Radiation	+		✓	
Solar Elements				
Solar Surface Features	+		✓	
Coronal Holes	+			
Solar Mag Field	+		✓	
Solar EUV	+			
Solar Radio Emission	+		✓	
Solar Radio Burst	+		✓	
Solar Energetic Particles	+	SSJ*		GOES
Solar X-rays	+			
Solar Flare	+		✓	
Interplanetary				
Solar Wind	+			
Interplanetary Mag Field	+			
Magnetospheric				
Geomagnetic Field	+	SSM	✓	
Trapped Radiation	+			GOES
Auroral Particles	+	SSJ/4		
Auroral Emissions	+	SSJ* OLS SSUV		
Electrojet	+	SSM SSJ/4 SSUV		
Ionospheric				
Electron Density	+	SSI/ES SSUV		
Ionospheric Irregularity	+	SSI/ES		
Auroral Trough	+	OLS SSM SSJ/4		
Neutral Atmosphere				
Neutral Density	+	SSM SSJ/4		

+ Possible Solution ✓ Being Accomplished with Deficiencies

DMSP Includes All Present and Planned Sensors channeltron, and is counted. Complete spectra of electrons and ions are taken every 1 second (table VI-2).

The Air Weather Service (AWS) applies the precipitating electron data to determine the auroral oval location along the track of the DMSP. Statistical techniques are then used to define the entire oval boundary. A new technique will use these data to define detail within the auroral zone, again by statistical techniques. Numerous DOD communication and radar customers operating near and through the auroral zone use the data provided. SSJ/4 data also represent the base of the radiation belts of the Earth. They will be an important input to the magnetospheric model with which AWS will analyze and forecast spacecraft anomalies. These data support space operations by identifying hazards to astronauts, as well as to computers and sensors in critical DOD systems. Another use planned for SSJ/4 data, combined with the topside ionospheric plasma monitor (SSI/E) and SSM, includes definition of heating in the high latitude ionosphere. With heating information, AWS will support satellite operations requiring atmospheric drag information, and DOD sensor operations that require infrared background noise (tables IV-3 through IV-4C).

B. TOPSIDE IONOSPHERIC PLASMA MONITOR (SSI/E)

The purpose of the SSI/E is to measure, at the altitude of the DMSP spacecraft, the ambient electron density and temperature, the ambient ion density, and the average ion temperature and molecular weight. The instrument consists of an electron sensor and an ion sensor mounted on a 2.5 m boom.

The electron sensor is a spherical Langmuir probe that operates in either of two modes. In mode 1, continuous electron density measurements are obtained by maintaining a constant voltage relative to the spacecraft on the outer grid of the probe. In order to offset possible spacecraft charging effects due to the design of the solar panels, this voltage is chosen (ideally) to maintain the SSI/E sensor within a few volts of the potential of the ambient plasma. In mode 2, a linear sweep voltage is applied to the outer grid; analysis of current collected versus applied voltage yields a measurement of electron temperature and vehicle potential. The normal operation of the electron sensor consists of a 64 second sequence that contains one 10 second sweep of mode 2, 2 seconds of dead time, and 52 seconds of mode 1.

The ion sensor is a planar aperture, planar collector sensor oriented to face into the spacecraft velocity vector at all times. The ion sensor operates in two modes similar to those of the electron sensor, so that both ion density and temperature are measured. Detailed analysis of the swept voltage

TABLE VI-2

SSJ/4 DATA SPECIFICATIONS

Environmental Parameters Sensed/Derived

–In situ sensor which measures flux of precipitating electrons and ions in 20 energy bands between 30 eV and 30 keV

–Flux range is energy dependent:

Electrons: 10-2 x 10^8/cm^2 sec sr eV
Protons: 1-5 x 10^6/cm^2 sec sr eV

Derived Quantities

–Auroral oval location

–Energy flux from magnetosphere

–E-region ionization rate and conductivity

Data Accuracy

–Particle flux ±1%

–Energy flux ±3.5%

–Average energy flux ±15-20%

–Auroral oval location ±1° latitude evening side, ±2° morning side

Data Coverage

–13 revolutions per day along track at a spatial resolution of about 0.1° latitude

–AFGL has developed techniques for interpolating data at 10° longitude increments, lower boundary location is accurate to 3°

Data Resolution

–0.1° latitude along track

Other Comments

–On all spacecraft beginning with F-6

data can also be used to determine the ion mean molecular weight and plasma scale height (tables IV-3 through IV-4C, and VI-3).

C. IONOSPHERIC PLASMA DRIFT/SCINTILLATION MONITOR (SSI/ES)

The ionospheric plasma drift/scintillation monitor (SSI/ES) is an improved version of the SSI/E, which has measured the ambient ionospheric thermal electron and ion density and temperature on several DMSP spacecraft. In addition to the Langmuir probe and planar ion collector, which make up the SSI/E, the SSI/ES has a plasma drift meter and scintillation meter. The drift meter measures the angle between the face of the sensor (which is nominally orthogonal to the spacecraft velocity vector) and the direction of arrival of the thermal ions that exist in the ionosphere at the spacecraft altitude. From this information and a knowledge of the spacecraft attitude and velocity, the two mutually perpendicular cross-track components of the plasma motion can be determined. This type of instrument, which is supplied by the University of Texas at Dallas, has operated successfully on the NASA Atmosphere Explorer and Dynamics Explorer spacecraft and on the DOD HILAT (P83-1) spacecraft. The scintillation meter is a high time resolution ion collector whose purpose is to make measurements of the variability of the ion density along the orbital track of the spacecraft. [Variations in ion density on spatial scales 10 m to 10 km can give rise to amplitude and phase fluctuations (scintillation) on radio waves that pass through the ionosphere.]

The ionospheric plasma/scintillation monitor sensor measures ambient electron and ion concentrations and their temperatures at the satellite location. Data are useful at all latitudes. The electron data are needed to provide a basis point for ionospheric electron density profiles. The ion data are needed to provide a basis for atmospheric chemistry models required to calculate entire electron density profiles using instruments like SSUV. The along-track resolution of this sensor will provide measurements of the ionospheric scintillation of radio signals that result from rapid changes in electron densities (table VI-3).

AWS will apply these data to base the top side of all their ionospheric models. These models support a wide variety of DOD communications and radar systems that must operate through, or using, the ionosphere. Scintillation data are also extremely useful to these customers.

SSI/ES combined with SSJ/4 and SSM will define high-latitude heating of the ionosphere leading to auroral zone definition of electron densities, required to support DOD communications

TABLE VI-3

SSI/E, SSI/ES DATA SPECIFICATIONS

Environmental Parameters Sensed/Derived

–Collects in situ electrons via boom mounted electrostatic analyzer and 3 body mounted planar electrostatic ion traps (Langmuir probes)

–Derived parameters include electron and ion concentrations and temperatures, and plasma drift and irregularities (△Ne/Ne)

Data Accuracy

–±20% for the following parameters over the indicated ranges

electron and ion density: 100-10^6/cm^3
electron temperature: 500-10,000 K
ion mass: 1-16 amu (H ions or O ions)
ion temperature: 500-10,000 K
irregularities (△Ne/Ne) 10^{-4}/1 (SSI/ES only)

Data Coverage

–13 revolutions of along track data per day

–At spacecraft altitude only

Data Resolution

–Along track (SSI/E, SSI/ES)

density: 1/0.25 km
mass, temp: 421/26 km

–Statistical algorithm used to estimate other values around a latitude belt

Other Comments

–SSI/E on F-6, F-7

–SSI/ES on F-8, and on

and radar operations; atmospheric drag characterization, used for DOD satellite operations; and auroral zone and limb background radiation, important to defining infrared noise for future surveillance systems (tables IV-3 through IV-4C).

D. FLUXGATE MAGNETOMETER (SSM)

The fluxgate magnetometer (SSM) was flown on the DMSP F-7 spacecraft to measure geomagnetic field fluctuations associated with geophysical phenomena, such as ionospheric currents flowing at high latitudes. Built by the Johns Hopkins University Applied Physics Laboratory, the SSM is a triaxial fluxgate magnetometer similar to instruments that have been flown on spacecraft for years. Unlike previous magnetometers, the sensor for this instrument is not mounted on a long boom (to isolate it from magnetic field fluctuations originating in the spacecraft), but is mounted on the outer skin of the satellite, under the thermal blanket. In spite of possible contamination of the geophysical data due to spacecraft stray fields, the signature of the field-aligned (Birkeland) currents can be found in the data (table VI-4).

The magnetometer device measures the three components of the magnetic field of the Earth, and currents in the high latitude ionosphere. Tentative plans call for SSM on DMSP F-12 and beyond. Used alone, the SSM can provide the tilt of the auroral mid-latitude boundary and the base of the magnetosphere. In combination with SSI/E and SSJ/4, the SSM will provide heating and electron density profiles in the high-latitude ionosphere.

AWS will use SSM auroral tilt data to support the over-the-horizon backscatter radar system. The same data will be used to determine the magnetic fields at the base of the radiation belts for their magnetospheric model. These data support spacecraft anomaly analysis and forecasting for many DOD space operations. Heating and electron density profiles support DOD drag calculations for satellite operations and numerous DOD radar and communications operations.

E. VACUUM ULTRAVIOLET SPECTROMETER (SSUV)

The vacuum ultraviolet spectrometer (SSUV) is an instrument that has been proposed to fly on future DMSP spacecraft for the purpose of measuring the electron density of the ionosphere above 90 km altitude. Follow-on to the auroral ionospheric mapper that was built by the Johns Hopkins Applied Physics Laboratory for the Air Force Geophysics Laboratory and flown on the STP HILAT (P83- 1) spacecraft, the SSUV would make use of emissions from the Earth's atmosphere to infer the electron density profile. The overall system concept includes the use of the vacuum ultraviolet (VUV) sensor itself, the

TABLE VI-4
SSM DATA SPECIFICATIONS

Environmental Parameters Sensed/Derived

– Measures, in Situ, Three Components of the Earth's Magnetic Field and Their Fluctuations

– Derived Quantity: Ionospheric Currents

Data Accuracy

– ± 14.6 Nanotesla Over a Range of 0 – 60,000

– Possible Constant Offset of Approx. 200 Nanotesla Along Each Axis

Data Resolution

– Along Track Resolution ± Equivalent to Approx. 0.4 in Track

– Sampling Rate 20 Vector Samples/Sec

Other Comments

– STP Sensor Flown On F-7 Only

– Follow-On Planned for F-12 and On

SSI/E sensor currently flown on DMSP, ground-based ionosonde data, and total electron content measurements from ground-based GPS receivers. The latter two sources of data would be used both to increase the data base that could be incorporated in the 4-D ionospheric model at Air Force Global Weather Central, and to refine the electron density profile inferred from the VUV data.

The VUV instrument, as currently conceived, would operate in four ionospheric subregions: (1) the daytime low- to mid-latitude region from 90 to 600 km altitude; (2) the nighttime mid-latitude regions from 250 to 600 km altitude; (3) the equatorial daytime; and (4) the auroral E-layer from 90 to 200 km altitude. Other regions, such as the polar cap, the auroral F-region and the nighttime equatorial region, are excluded for various reasons. The spatial resolution of the inferred electron density profile is envisioned as 500 by 500 km everywhere except in the aurora region, where it would be 50 by 50 km. The method of operation of the VUV instrument in each of these four regions is described below (and in table VI-5).

1. Daytime Low- to Mid-latitudes

In the daytime low- to mid-latitudes, the emissions from atomic oxygen at 1,356 angstroms, and from one or more lines of the nitrogen Lyman Birge-Hopfield (LBH) bands in the 1,500 to 1,700 angstrom region will be measured. A spectrometer will be scanned from limb to limb and through the nadir in order to map out these emissions from the Earth's upper atmosphere. The concept involves inferring a measure of the solar flux that causes ionization in the daytime ionosphere and the ratio of the density of oxygen and nitrogen, coupled with theoretical models of photoionization and photoelectron transport, to calculate, from the first principles, the electron density profile. An additional measurement of the electron density by the SSI/ES will tie down the electron density at the altitude of the DMSP spacecraft.

2. Nighttime Mid-latitudes

In the nighttime mid-latitudes subregion, the ratio between the emissions from atomic oxygen at 1,356 angstroms and 6,300 angstroms has been shown to correlate well with $h_m F_2$, and the absolute flux at 1,356 angstroms gives a measure of the electron number density at the peak of the F_2 region. Detailed analyses are currently being carried out to determine the size optics required to make accurate measurements of these weak emissions.

3. Auroral E-Layer

In the auroral E-layer, the ionization is produced by ener-

TABLE VI-5

SSUV DATA SPECIFICATIONS

Environmental Parameters Sensed/Derived

–Measures ultraviolet and (possibly) visible radiation emitted by the atmosphere

–Spectrometric measurements in the 100-1800 Å spectral region (with emphasis on atomic oxygen emission at 1356 Å and the molecular bands in the 1500-1700 Å region)

–Photometric measurements of the atomic oxygen emissions at 1356 and 6300 Å

–Derived geophysical parameter is the vertical profile of the electron density above approx. 90 km altitude, from which total electron content can be calculated

Data Accuracy

–TBD

Data Coverage

–Daily coverage of globe, with exception of nighttime low latitude and equatorial region, auroral F-region and polar cap

–Overlapping data from consecutive revs–like OLS

–Horizontal swath width approx. ±3,000 km from nadir

Data Resolution

–Horizontal resolution

50 x 50 km in auroral region
500 x 500 km elsewhere

–Vertical resolution = TBD

Other Comments

–Planned for flight on DMSP F-16

–Proof of concept on Space Test Program Polar Bear (1986) getic (KeV) electrons precipitating from the Earth's magnetosphere. The emissions from atomic oxygen at 1,356 angstroms and from the molecular nitrogen LBH bands provide a measure of the incoming electron energy spectrum and flux; this information is then used, in an equilibrium theoretical code, to deduce the electron density produced by the auroral electrons.

4. Equatorial Daytime

In equatorial daytime, the situation is complicated by large-scale electric fields, which, at different times of the day, raise or lower the ionosphere. Presumably, the same atmospheric emissions that are proposed for use at mid-latitudes can be used, but some additional measurement is needed to infer the effect of the electrical field. As currently conceived, the VUV sensor consists of one spectrometer, primarily for use during the day, and two or three photometers for use at night. The spectrometer is a 1/4 m Ebert-Fastie instrument designed to cover the 100 to 1800 angstrom region of the spectrum, while the photometers view 6,300 angstrom and 1,356 angstrom emissions.

The VUV imager for DMSP flights F-16 and beyond will provide electron density profiles below the spacecraft track and 400 km each side of the track. These profiles are derived from observations of differential emission and absorption of airglow in four to six VUV and visible frequencies in mid- and equatorial latitudes. This use requires SSI/E. In addition to electron density profiles, the SSUV will also provide auroral zone images and information on optical and ultraviolet background noise.

AWS will apply the electron density profiles to support a wide variety of communicators and radar operators. Accurate location of the auroral zone provides noise and interference data to the same customers, and background data in support of surveillance systems. Airglow data support the same customers, worldwide (tables IV-3 through IV-4C).

F. SPACE RADIATION DOSIMETER (SSJ*)

The purpose of the space radiation dosimeter (SSJ*) is to measure the radiation dose from both electrons and protons, as well as the number of nuclear star events occurring behind four different thicknesses of aluminum shielding. In addition, it provides some information on the integral flux of electrons and protons at energies above the thresholds defined by the shields. The experiment provides information on the relationship between the flux of high-energy particles incident to the spacecraft, and the actual radiation dose to which microelectronic components are exposed. This information is required for determination of the relationship between variations in the Earth's radiation belts and the behavior and lifetime of microelectronic components.

The basic measurement technique is to determine the amount of energy deposition occurring in a simple solid-state detector from particles with sufficient energy to penetrate an omnidirectional aluminum shield of known thickness. The solid-state device used as the active measuring element is a p-i-n diffused junction silicon semiconductor with a guard ring. The specific devices are from the YAG series manufactured by EG&G, Inc. With such devices, a threshold of 50 KeV for the energy deposition in the device can be set. This allows the detection of high-energy particles, as well as most of the bremsstrahlung produced in the shield. Although many detectors in the past have used volume-type devices (detection area dimensions comparable to device thickness), the devices used in the SSJ* are of the planar type (detection area dimension larger compared to thickness). This choice was made in order to most nearly model real microelectronic components that are mostly planar (table VI-6).

Each device is mounted behind a hemispheric aluminum shield. The aluminum shields are chosen to provide electron energy thresholds for the four sensors of 1, 2.5, 5, and 10 MeV, and for protons of 20, 35, 51, and 75 MeV. The 1 MeV threshold sensor has a detector area of .051 cm^2, and the remaining three each have areas of 1.00 cm^2. Both particles that penetrate the shield and bremsstrahlung produced in the shield that impact the active element will deposit energy in the device producing a charge pulse. The charge pulse is shaped and amplified. The pulse height is proportional to the energy deposition in the detector. The characteristics of the detector and the threshold are such that the energy depositions between 50 KeV and 1 MeV are summed to give the low linear energy transfer (LOLET) dose. Depositions between 1 MeV and 10 MeV are summed to give the high linear energy transfer (HILET) dose, and depositions above approximately 40 MeV are counted as very high linear energy transfer (VHLET) events. The LOLET dose comes primarily from electrons, high-energy protons (above 100 to 200 MeV), and bremsstrahlung. The HILET dose is primarily from protons below 100 to 200 MeV. The VHLET dose comes from the nuclear star interactions of high-energy protons, from heavier cosmic rays, and from the very small percentage of trapped radiation particles that have long path lengths in detectors.

The dose is taken to be directly proportional to the total energy deposited in the detector. Each pulse is analyzed to determine whether it will be counted for electron or proton dose or a nuclear star event. The pulse height is then digitized and added to the sum of all other pulse heights measured in the accumulation interval. In addition, the total

TABLE VI-6

SSJ* DATA SPECIFICATIONS

Environmental Parameters Sensed/Derived

–Measures the flux of electrons and protons in the natural radiation environment with energies greater than four threshold levels

–Derived parameters are accumulated radiation dose rads (Si) electrons and protons

–Proton threshold levels are 20, 35, 51, 75 MeV

Data Accuracy

–±5%, for electron fluxes not exceeding 10^{-5} ±80% electrons/cm^2–sec above 1 MeV, and proton fluxes not exceeding 10^3 ±80% protons/cm^2–sec above 20 MeV

Data Coverage

–Designed to measure maximum accumulated dosage of

10^5 rads (Si) ±80% electrons
10^4 rads (Si) ±80% protons
over the course of F-7 DMSP lifetime

–Daily global coverage at spacecraft altitude

Data Resolution

–N/A–data collected continuously throughout the orbital track

Other Comments

–Flown as a Space Test Program sensor on F-7

–Also to fly on CRRES

number of pulses measured in the accumulation interval is recorded for both electrons and ions. In the absence of significant bremsstrahlung, this number of counts should be directly proportional to the integral flux of electrons and ions above the threshold produced by the aluminum shield.

G. GAMMA AND X-RAY SPECTROMETER (SSB/A)

The scanning x-ray spectrometer (SSB/A) detects x-rays from bomb debris or those produced by the bremsstrahlung process when electrons precipitate from the Earth's radiation belts. Those electrons interact with atmospheric atoms and molecules, primarily in the altitude range of 100 to 150 km. By sensing these x-rays, the SSB/A can provide the location of the aurora as it orbits the Earth. Through well-proven data analysis techniques, it can measure the enhancement in the electron density and conductivity in the E-region of the Earth's auroral ionosphere (table VI-7).

The SSB/A is developed and produced by the Space Sciences Laboratory of the Aerospace Corporation. The major improvement over its predecessors is its scanning capability, so that a swath of the Earth's atmosphere 3,000 km wide is observed with a horizontal resolution of 100 km. The two detector heads scan in opposition across a 100 degree arc perpendicular to the orbital plane and approximately centered on nadir. One of the two heads carries the high-energy sensor, which spans the energy range 15 to 100 KeV, while the other carries the low-energy sensor, which senses x-rays with energies in the 2 to 7 KeV range.

The ionization rate and conductivity of the E-region can be calculated from the energy spectrum of the bremsstrahlung x-rays measured by the SSB/A. The energy spectrum of the precipitating electrons is deduced from the x-ray spectrum, and is used in calculating the energy transport through the atmosphere. This yields the energy deposition and ionization rates as functions of altitude. The equilibrium electron density profile can be derived from the ionization rate and known recombination rates; given the neutral density profile, the conductivity profile can be derived. This scanning x-ray spectrometer is an Air Force Technical Applications Center (AFTAC) payload, which provides the location and energy spectrum of gamma and x-ray sources in the atmosphere (table IV-3).

H. GAMMA AND X-RAY DETECTOR (SSB/S and SSB/X)

The SSB/S and SSB/X x-ray detectors are follow-ons to the SSB/A. Only one SSB detector will be flown on a DMSP satellite (table VI-8).

TABLE VI-7

SSB/A DATA SPECIFICATIONS

Environmental Parameters Sensed/Derived

–CdTe detectors sense x-ray radiation from the Earth's atmosphere in four energy bands: 15-30, 30-60, 60-120, 120 keV

–Proportional counters measure x-rays in 24 logarithmically spaced energy bands between 14 and 70 keV

–Lyman alpha sensor detects prominent proton events

–Two Geiger counters detect energetic electrons that produce local x-ray background

–Primary function is to detect nuclear detonations

–Parameters capable of being derived include ionospheric conductivity and vertical electron density profiles in the D and lower E regions of the ionosphere; total auroral x-ray index (TAXI)

–Derived geophysical parameters:

  –location and distribution of aurora
  –precipatating electron flux
  –ionization rate versus altitude
  –equilibrium auroral E-region electron density profile
  –E-region conductivity

Data Accuracy

–Energy levels measured to within ±18%

–Retrieved electron density profiles agree within error bars of ground truth data (±30%)

–TAXI is a qualitative index of auroral acitivity

Data Coverage

–Daily global coverage

–Horizontal swath width 1500 NM, –57° to +48° FOV

–Data updated every 50 minutes

Data Resolution

–55 NM along track

–110 NM across track

Other Comments

–One of a kind sensor on F-6, no longer operational

–Candidate sensor for future ionospheric measurements

TABLE VI-8

SSB/S AND SSB/X DATA SPECIFICATIONS

Environmental Parameters Sensed/Derived

- **SSB/S:**
  - Two Arrays of Four 1 cm Diameter CdTe Detectors Sense X–Rays in Four Energy Bands >45 keV, >75 keV, >115 keV, >165 keV
  - NaI Detector Senses Scintillation
  - All Three Detectors are Scanned by Rotating the Sensor Assembly
  - Primary Function is to Detect Nuclear Debris From Nuclear Detonations
- **SSB/X:**
  - CdTe Detectors Sense X–Rays in Three Energy Bands >60 keV, >150 keV and >375 keV
  - Two Nonscanning Sensors Look Left and Right of the Ground Track
  - Primary Function is to Detect Nuclear Debris From Nuclear Detonations

I. SPACE ENVIRONMENT MONITOR (SEM)

The overall NOAA A SEM consists of two sensor and analog electronics sections that feed a common data processing unit (DPU). The DPU also contains the main DC-DC converter for the whole system, and all interfaces with the S/C data, command, and power subsystems. The division of the detectors into the two groups reflects the two different detector technologies used to cover the wide energy range between >300 eV and >60 MeV. The two detector systems will be described first, followed by a description of the DPU.

1. Total Energy Detector (TED)

The total energy detector (TED) measures electrons and positive ions in the energy range 300 eV to 20 keV. Four separate detector assemblies measure the negatively charged and positively charged particles, respectively, at two angles: one approximately parallel to the magnetic field at high latitudes and the other at 30° W. of the field. This approximately distinguishes between those particles that will lose their energy to the upper atmosphere and those that will be "mirrored" by the magnetic field.

The detector assembly (fig. VI-1) consists of a cylindrical electrostatic analyzer with approximately a 13 percent energy resolution, followed by a "spiraltron" channel electron multiplier detector, which produces a relatively large pulse of charge for every event counted independently of the original particle energy. Preaccelerator fields of appropriate polarity are applied between the electrostatic analyzer exit and the spiraltron cathode to ensure that even the lowest energy particles produce enough electrons at the cathode surface to be counted.

The electrostatic analyzer sorts particles by their charge and energy. However, for simplicity of ground processing, and to minimize telemetry rate requirements, the main output of the instrument, as its name implies, is the total incident energy flux. This measurement is accomplished by using a piecewise linear approximation to an exponential ramp voltage applied to the electrostatic analyzer. The total data acquisition interval, during which the analyzer is swept from 0.3 keV to 20 keV, is divided into 11 intervals plus one interval in which the analyzer voltage is held at zero to check for events not arising from analyzed particles. During the eleven intervals, a prescaler is adjusted by factors of two in such a way as to weight each contribution to the final accumulated event total in proportion to its energy content, thus arriving at the total energy. An additional piece of information derived for each sweep is the energy interval containing the maximum number of events, thus giving an indication of the predominant

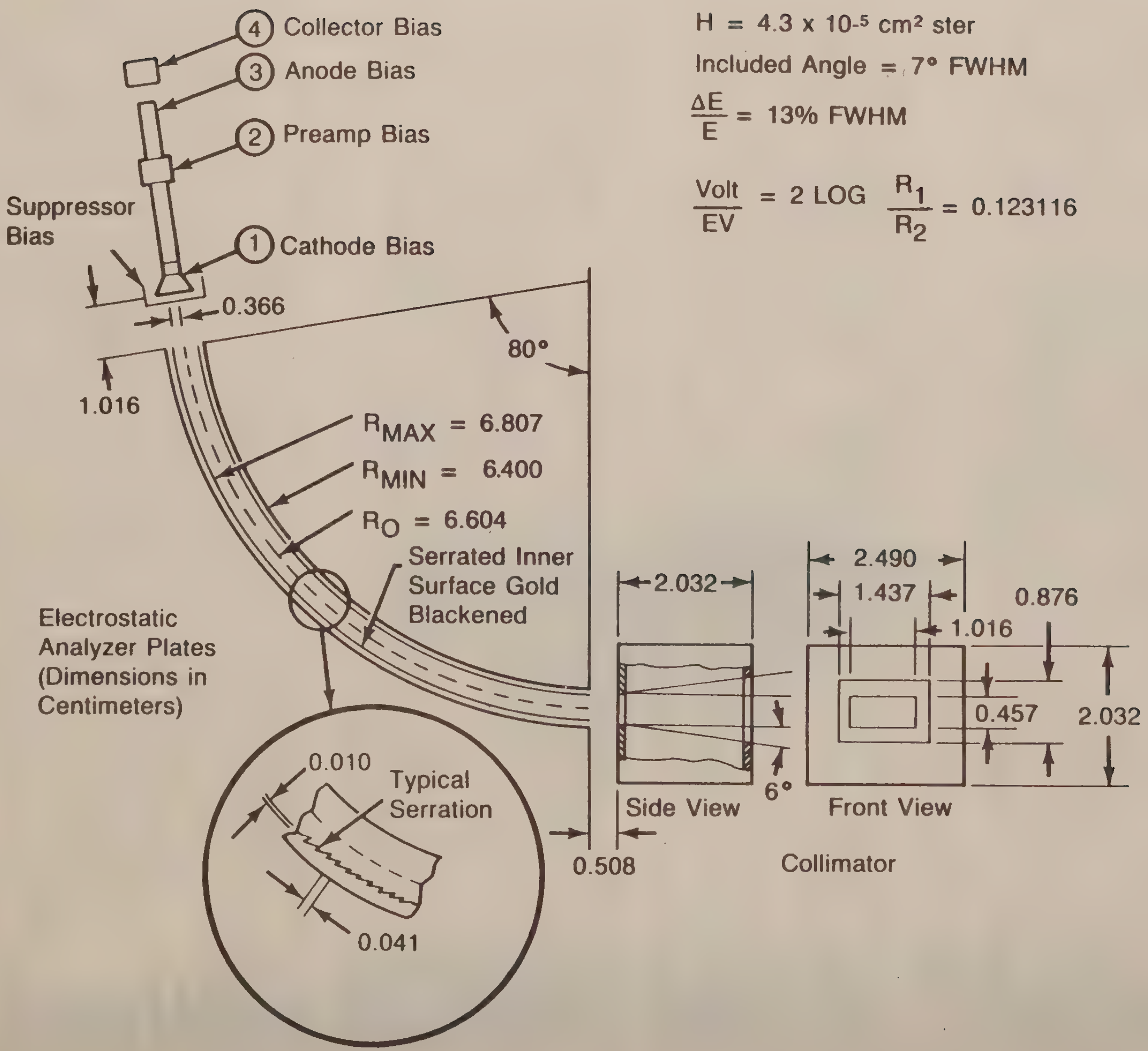

H = 4.3 x 10-5 cm² ster
Included Angle = 7° FWHM
ΔE/E = 13% FWHM
Volt/EV = 2 LOG R1/R2 = 0.123116
4 Collector Bias
3 Anode Bias
2 Preamp Bias
1 Cathode Bias
Suppressor Bias
0.366
1.016
80°
RMAX = 6.807
RMIN = 6.400
RO = 6.604
Serrated Inner Surface Gold Blackened
Electrostatic Analyzer Plates (Dimensions in Centimeters)
0.010
Typical Serration
0.041
0.508
2.032
Side View
6°
2.490
1.437
1.016
0.876
0.457
2.032
Front View
Collimator

Figure VI-1
TED Spiraltron Detector and Electrostatic Analyzer Assembly

energy in the incident spectrum. More detailed information on the incident spectrum is obtained at a slower rate by telemetry in submultiplexed words of some of the individual accumulated event totals during the separate sectors of the energy sweep. Figure VI-2 shows some details of the sweep.

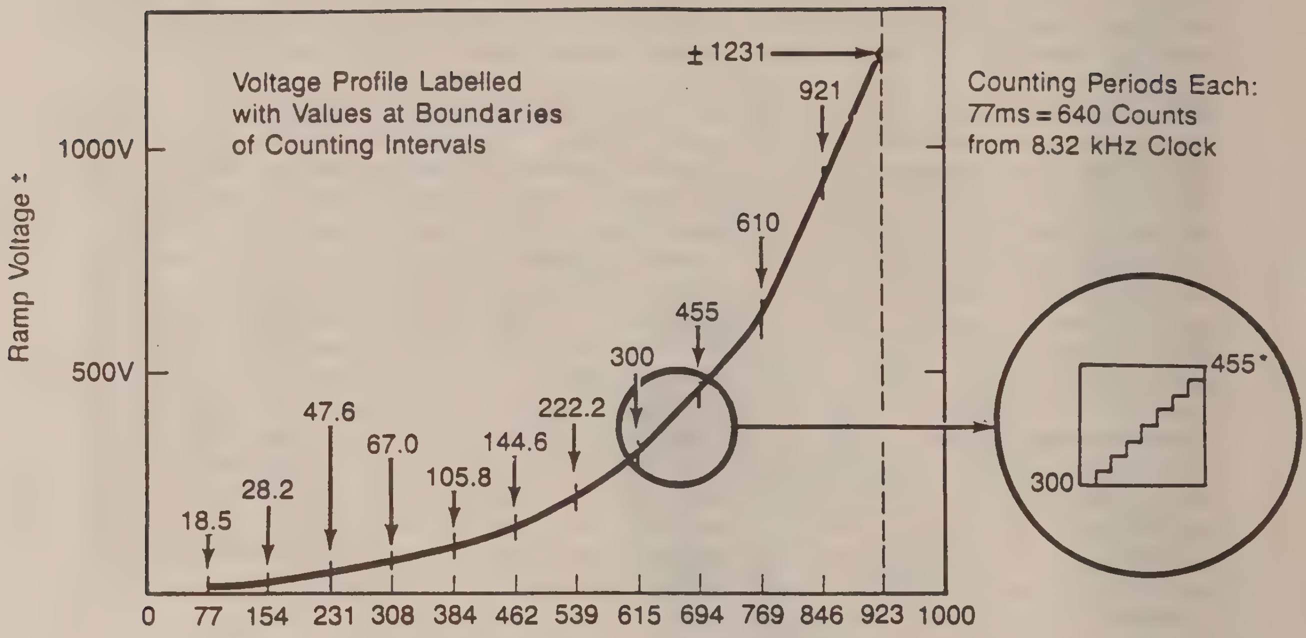
A functional block diagram of the TED detector and analog electronics is shown in figure VI-3. The basic signal chain between the detector spiraltrons and the logic pulse output to the DPU is quite straightforward. Two signal chains are used, which are multiplexed sequentially between the detectors at 0° and those at 30° to the magnetic field. Each consists of linear amplification and pulse shaping followed by an amplitude discriminator. However, considerable complication is introduced by the need to allow for the loss of electron multiplication gain that occurs over the lifetime in orbit of the detectors. This is basically a function of the number of events detected. The gain can be adjusted by varying the bias voltage across the multiplier section; eight voltage steps are provided for this purpose. To determine the correct voltage setting, a crude distribution of pulse heights from each detector is obtained by selecting four discrimination levels using a combination of gain change and discriminator level change.

Provision is made for automatic in-flight calibration (IFC) under control of a sequence generated by the DPU, which is started by ground command. Ramp amplitude modulated pulses are applied to the charge-sensitive preamplifiers to measure the actual discriminator levels by analysis of the instrument output data on the ground. The IFC sequence also cycles the discriminator levels without applying artificial pulses, so that the amplitude distribution of the detector outputs is obtained using natural events.

2. Medium-Energy Proton and Electron Detector (MEPED)

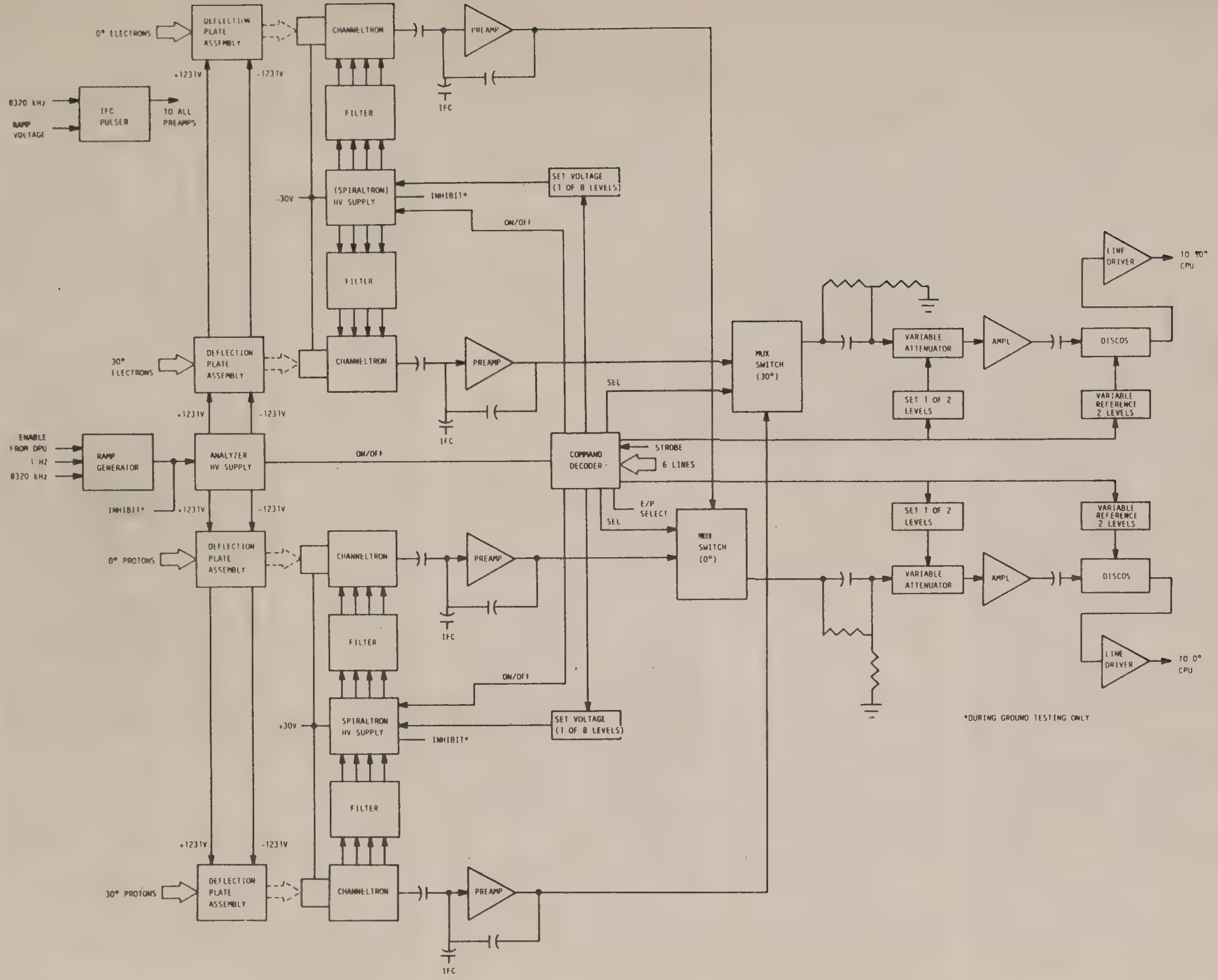
The medium-energy proton and electron detector (MEPED) uses solid-state silicon detectors to detect electrons, protons, and alpha particles over a range of >30 keV to <80 MeV in energy. The silicon detectors are linear detectors that produce a quantity of charge directly proportional to the quantity of energy deposited in the active volume of the detector by an incident particle. This makes possible the energy analysis of the particle flux by analyzing the distribution of the charge pulses produced by the incident particles. Separate pairs of proton and electron "telescopes" are used, pointing at 0° and 90°, respectively, to the magnetic field at high latitudes.

The proton telescope consists of two elements mounted behind a sweeping magnet, and responds to proton (actually all posi-



Channel Energy (Kev)	Ramp Range (V)	Energy Interval (Kev)			Data Channel Label	Number of Pre-Scaling Bits in F_D (a) comp
		Width	Center	Width Center		
0	0	---	---	---	BKGND	---
0.300- 0.458	18.5- 28.2	0.158	0.379	0.42	DE 1	5
0.458- 0.773	28.2- 47.6	0.315	0.616	0.51	DE 2	4
0.773- 1.088	47.6- 67.0	0.315	0.931	0.34	DE 3	4
1.088- 1.718	67.0- 105.8	0.630	1.403	0.45	DE 4	3
1.718- 2.349	105.8- 144.6	0.630	2.033	0.31	DE 5	3
2.349- 3.610	144.6- 222.2	1.261	2.979	0.42	DE 6	2
3.610- 4.870	222.2- 299.8	1.261	4.250	0.30	DE 7	2
4.870- 7.392	299.8- 455.0	2.522	6.131	0.41	DE 8	1
7.392- 9.914	455.0- 610.2	2.522	8.653	0.29	DE 9	1
9.914-14.957	610.2- 920.6	5.043	12.436	0.41	DE10	0
14.957-20.000	920.6-1231.0	5.043	17.479	0.29	DE11	0
0.300-20.0	18.5-1231.0				F_D (a)	

Figure VI-2
Ramp Characteristics


0° ELECTRONS
DEFLECTION PLATE ASSEMBLY
CHANNELTRON
PREAMP
IFC
+1231V
-1231V
8320 kHz
RAMP VOLTAGE
IFC PULSER
TO ALL PREAMPS
FILTER
SET VOLTAGE (1 OF 8 LEVELS)
-30V
(SPIRALTRON) HV SUPPLY
INHIBIT*
ON/OFF
FILTER
30° ELECTRONS
DEFLECTION PLATE ASSEMBLY
CHANNELTRON
PREAMP
IFC
+1231V
-1231V
SEL
MUX SWITCH (30°)
VARIABLE ATTENUATOR
AMPL
DISCOS
LINE DRIVER
TO 30° CPU
SET 1 OF 2 LEVELS
VARIABLE REFERENCE 2 LEVELS
ENABLE FROM DPU
1 HZ
8320 kHz
RAMP GENERATOR
ANALYZER HV SUPPLY
ON/OFF
COMMAND DECODER
STROBE
6 LINES
INHIBIT*
+1231V
-1231V
E/P SELECT
SEL
SWITCH (0°)
SET 1 OF 2 LEVELS
VARIABLE REFERENCE 2 LEVELS
VARIABLE ATTENUATOR
AMPL
DISCOS
LINE DRIVER
TO 0° CPU
0° PROTONS
DEFLECTION PLATE ASSEMBLY
CHANNELTRON
PREAMP
IFC
FILTER
ON/OFF
+30V
SPIRALTRON HV SUPPLY
SET VOLTAGE (1 OF 8 LEVELS)
INHIBIT*
FILTER
+1231V
-1231V
30° PROTONS
DEFLECTION PLATE ASSEMBLY
CHANNELTRON
PREAMP
IFC

*DURING GROUND TESTING ONLY

Figure VI-3
TED Functional Block Diagram

tive ions) >30 keV in five discrete energy intervals. Low-energy electrons are removed by the broom magnet, and higher energy electrons and ions are discriminated against using anticoincidence logic between the two elements. The "electron" sensor consists of a single detector mounted behind a thin nickel foil, and responds to electrons >30 keV and positive ions <200 keV in the three integral energy channels. The true electron response can be calculated by subtracting the "proton" response determined by the proton telescope. The proton telescope also uniquely identifies the intensity of ions with Z>2 in one energy interval.

These omnidirectional sensors are essentially identical to units flown on the GOES-2 and -3 spacecraft, and similar to those flown on the earlier TIROS "wheel" spacecraft. They comprise three nominally identical Kevex Si(Li) solid state detectors of 0.50 cm^2 area by 3 mm thickness, independently mounted under spherical shell moderators, to provide sensitivity in three integral data channels. The viewing angle of each of the detectors has a full opening angle of 120^o in the zenithal direction as mounted.

The overall shielding of the instrument corresponds to 80 MeV for protons, and therefore the detectors respond to protons of energy >80 MeV over the entire 4 pi solid angle as indicated above. The effective solid angle of the flight units is, of course, somewhat less, determined by the shielding provided by the satellite body itself. Because of the usual relatively steep spectrum for both galactic and solar cosmic rays, the counting rates of the 16 to 80 MeV and 36 to 80 MeV channels are not severely compromised by the >80 MeV background. However, the response of the 80 to 215 MeV detector will be uncertain to factors of the order of 2.

Calibration of the omnidirectional detectors was performed at the Harvard University Cyclotron Facility, which, using a uniform axial proton beam, confirmed the detector thresholds for the instrument. A schematic diagram of the detector is shown in figure VI-4.

Each detector has its own charge-sensitive preamplifier. The outputs of each of the six preamps associated with the 0^o and 90^o telescopes are multiplexed into three signal chains consisting of linear amplifiers and pulse-shaping networks, which drive a set of pulse amplitude discriminators. The three high-energy integral channels have individual, separate, signal chains, with only a single discriminator. These discriminators, either directly or in logical combination or, in the case of the proton telescopes, after time coincidence gating and logical combination, produce logic pulses for transmission to the DPU that correspond to the intensity of a given incident particle species in particular energy bands.

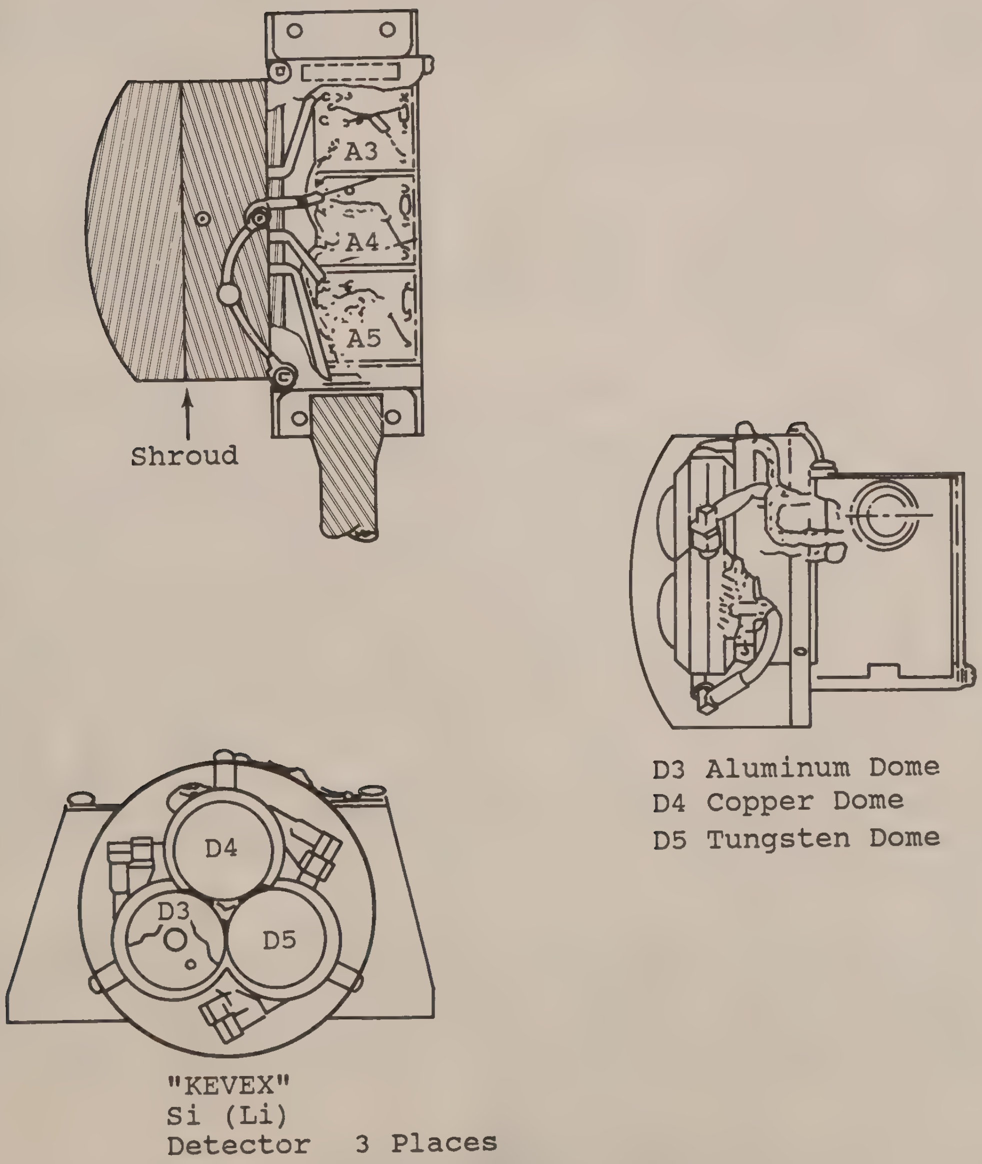

A3
A4
A5
Shroud
D3 Aluminum Dome
D4 Copper Dome
D5 Tungsten Dome
D4
D3
D5
"KEVEX"
Si (Li)
Detector 3 Places

Figure VI-4
Omnidirectional Spectrometer

It is of interest to note that at the lowest threshold of this sensor, 30 keV, the linear signal electronics is detecting an event producing only 104 electrons at the input to the charge-sensitive preamplifier.

The IFC arrangements provide for ramp-modulated test pulses to be introduced at each preamplifier input, under control of a ground command-initiated sequence. The instrument output data can then be analyzed on the ground to check the level of each discriminator threshold, the system noise, and the long-term operational stability.

3. Data Processing Unit (DPU)

The data processing unit (DPU) takes the logic level pulses representing particle events in particular categories and processes them to provide data on the flux and spectrum for telemetry transmission to the ground. A block diagram of the DPU is shown in figure VI-5.

In the case of the MEPED and High Energy Proton and Alpha Detector (HEPAD) data, the basic DPU operation is an accumulation of the number of events occurring in a fixed interval. As the dynamic range of the observed flux is very large, the original accumulated 19-bit number is converted to an 8-bit quasi-floating point representation to reduce the telemetry requirement and provide an approximately constant percentage accuracy. The various channels are multiplexed between accumulators and into the telemetry format to provide a sampling rate commensurate with the importance and anticipated rate of variation of the particular channel. For the TED data, the DPU carries out the integration over the energy sweep to obtain the total energy, and detects the energy interval containing the maximum flux. Alternative telemetry formats can be selected for the TED data to provide emphasis on different features of the TED submultiplexed data for different application.

The DPU also houses the DC/DC power converter, the command and timing interface, and an analog multiplexer and A/D converter, which provides SEM housekeeping data to the TIP data stream. In addition to the latter, a more limited number of basic voltages and temperatures are monitored by the TIP analog and digital B systems.

4. Application and Data Examples

a. TED. The TED instrument in the TIROS-N SEM monitors the total energy fluxes deposited in the atmosphere by precipitating charged particles (energies between 0.3 and 20 keV). These particles, which come from the Earth's magnetosphere, are deposited at high latitudes in the auroral zone and are

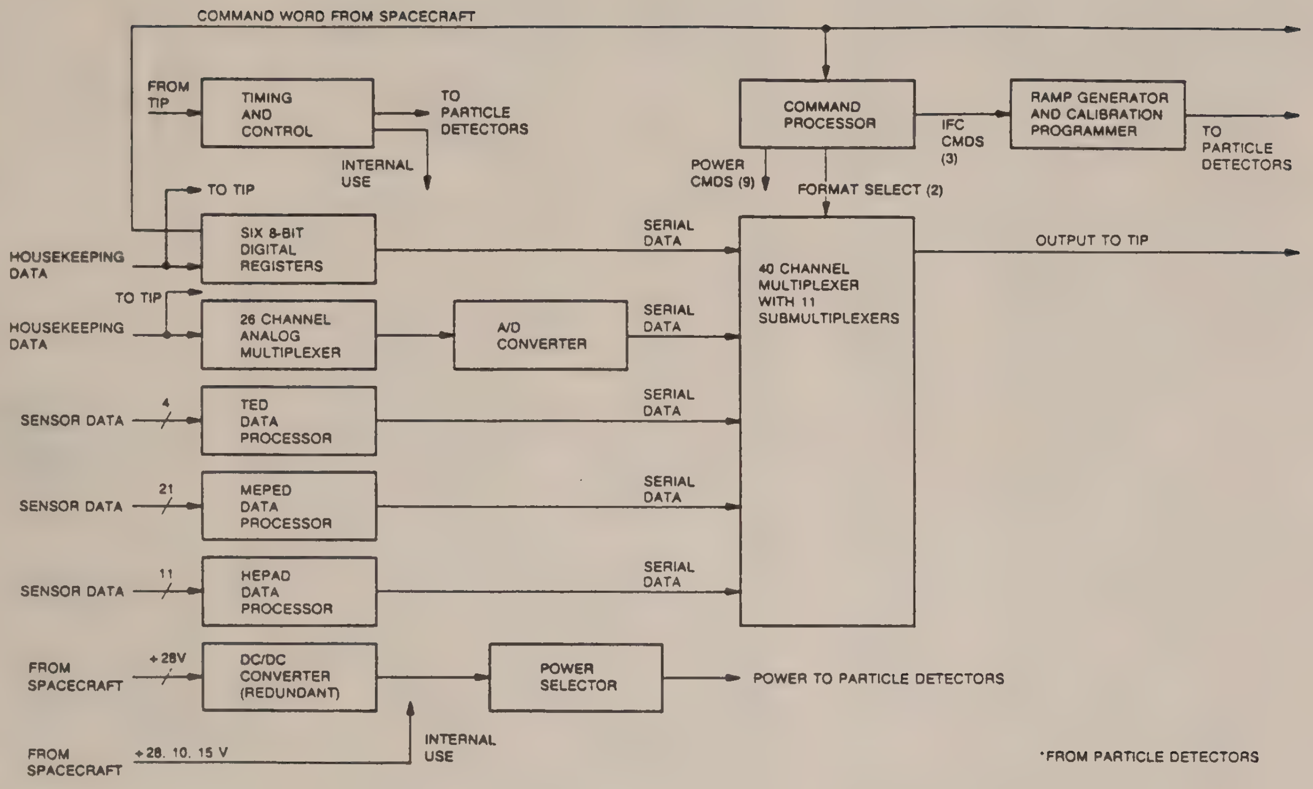

COMMAND WORD FROM SPACECRAFT
FROM TIP
TIMING AND CONTROL
TO PARTICLE DETECTORS
INTERNAL USE
TO TIP
COMMAND PROCESSOR
POWER CMDS (9)
FORMAT SELECT (2)
IFC CMDS (3)
RAMP GENERATOR AND CALIBRATION PROGRAMMER
TO PARTICLE DETECTORS
HOUSEKEEPING DATA
SIX 8-BIT DIGITAL REGISTERS
SERIAL DATA
40 CHANNEL MULTIPLEXER WITH 11 SUBMULTIPLEXERS
OUTPUT TO TIP
TO TIP
HOUSEKEEPING DATA
26 CHANNEL ANALOG MULTIPLEXER
A/D CONVERTER
SERIAL DATA
SENSOR DATA
4
TED DATA PROCESSOR
SERIAL DATA
SENSOR DATA
21
MEPED DATA PROCESSOR
SERIAL DATA
SENSOR DATA
11
HEPAD DATA PROCESSOR
SERIAL DATA
FROM SPACECRAFT
+28V
DC/DC CONVERTER (REDUNDANT)
POWER SELECTOR
POWER TO PARTICLE DETECTORS
FROM SPACECRAFT
+28. 10. 15 V
INTERNAL USE
*FROM PARTICLE DETECTORS

Figure VI-5
TIROS-N DPU Block Diagram

responsible for both the visible aurora and ionospheric disturbances. Thus, the data provide a measure of the intensity and extent of the effects on radio communications and navigation equipment operating with auroral zone reflections. In addition to disturbing the ionosphere, the energy deposited in the upper atmosphere is sufficient at times to produce significant warming and expansion. This produces density variations that affect the drag experienced by low-orbiting navigation satellites. The resultant circulation in the upper atmosphere is responsible for changes in the composition and equilibrium of the ionosphere over a wide region of the Earth, and may be responsible for some of the correlations that have been observed between solar activity and weather in the lower atmosphere. Several useful indices of activity are derived from the data. Among these are:

- The most equatorward latitude for which the energy flux exceeds a given value. This provides an index of the extent of the region of the energy influx.
- The maximum energy influx recorded during a given satellite pass. This is equivalent to a measure of the greatest disturbance beneath the satellite track.
- The integrated total energy input over the whole auroral zone. This value weights both the intensity and the extent of the energy input.

Principles of Operation of the TED Sensor. TIROS-N TED is basically a conventional cylindrical plate electrostatic analyzer, together with a channel electron multiplier charged-particle detector. A voltage difference is impressed between the analyzer plates. The polarity of this voltage determines whether positively charged ions (assumed always to be protons) or negatively charged particles (assumed to be electrons) are to be detected. The magnitude of this voltage selects a band of particle energies centered at some energy, E, for which the particles are passed through the analyzer. The channel electron multiplier counts these particles.

Two separate electrostatic analyzer charged-particle detector systems are included in the TED. These view charged particles coming from different directions, so that observations can be made of the directional energy flux at two different angles to the local geomagnetic field direction. One of these detectors is viewing outward, parallel to the Earth center radial vector, so that it measures charged particles whose velocities are toward the Earth along this radial vector. The other detector views at an angle of 30 degrees in respect to the first. At high latitudes in the auroral zone, these two measurements correspond approximately to those particles that are precipitating parallel to the local magnetic field, and will be absorbed in the atmosphere, and those at a sufficient angle to the field so that they will "mirror" and not be absorbed.

Each of the two particle detector systems alternates between measuring electrons and measuring protons or other positive ions. The time taken for a full cycle is 2 seconds. During the first half-cycle (1 second) both instruments are devoted to measuring electrons. The 1 second period is divided into 13 equal segments. During the first 1/13 second, a background measurement is taken; during the final 1/13 second, the instrument undergoes a reset sequence during which no data are taken. During the remaining 11/13 second, the analyzers are swept from an energy of 300 eV to an energy of 20,000 eV. The total number of counts accumulated by the detector during this sweep is telemetered to the ground as a measure of the integrated (from 300 to 20,000 eV) directional energy flux carried by the electrons observed by that particular detector. During the second half of the cycle the process is repeated for protons.

b. MEPED. The principal operational use of the particle detectors that comprise the MEPED is the reliable and accurate determination of the flux and spectrum of energetic particle fluxes produced by the sun during solar flares and other disturbances. These energetic particles, mostly protons in the energy range of some tens of kilovolts to greater than a billion electronvolts in major events, are a radiation hazard to astronauts and systems in space, and produce ionization of the Earth's upper atmosphere and ionosphere, which has significant effects on radio propagation in the polar regions. The particles themselves, and their atmospheric secondaries, may, in extreme cases, pose a significant radiation hazard to passengers and crew of high-flying aircraft. These data therefore provide an important input into the data base of the NOAA Space Environment Services Center (SESC) for real-time analysis and distribution to their NOAA customers.

The extension of the energy range to lower energy protons in the NOAA A SEM, as well as the continuation of the data base, also provides an important information source for validation of photochemical models of the stratosphere and ionosphere. There also is evidence that these data have relevance to studies of the possible climatological effects of solar activity. Studies have shown that the additional production of nitric oxide (NO) in the stratosphere by large solar proton events produces substantial reductions in the Earth's stratospheric ozone layer concentration. Nitric oxide, through several coupled catalytic reactions, is efficient in removing ozone in the atmosphere. Atmospheric ozone is of course important in screening us from a large portion of the sun's damaging ultraviolet radiation. Large variations in the total ozone content appear to be responsible for major faunal extinctions in the Earth's past, and may have important climatological significance.

Additionally, however, the lower energy protons detected by the MEPED can provide significant information on the state of, and dynamical processes occurring within, the magnetosphere. Many questions still exist in terms of the entry of solar particles into the magnetosphere, and the subsequent processes that act upon them. Low-energy protons, because their behavior is much more determined by the geomagnetic field, are able to be used as tracers in defining the properties of the field, and the electromagnetic processes they experience. The lowest energy threshold of the MEPED has been reduced to 30 keV in channel P1 from the 270 keV threshold of the monitors aboard the previous TIROS series. This reduction of minimal threshold enhances the tracer use of solar protons.

Studies have shown that in the early part of at least some low-energy solar events, an asymmetry had been observed between the fluxes seen over the northern and southern polar caps. In comparison with corresponding measurement of the particle fluxes outside the magnetosphere, this asymmetry appeared to support the hypothesis that the interplanetary magnetic field was directly connected to the hemisphere showing the greater flux. The sense of the connection would depend on the then direction of the interplanetary field, whether toward or away from the sun. In this manner, observation of the low-energy fluxes of solar protons over the polar caps can provide information about the topology of the geomagnetic fields at high latitudes, as well as about the mean orientation of the interplanetary field. Further, solar protons of a given energy have essentially free access to the polar caps of the Earth to some minimal geomagnetic latitude that is dependent upon energy, the so-called cutoff latitude. The cutoff latitude for a given energy is dependent on the local time, an expression of the longitudinal asymmetry of the magnetospheric fields, and is dependent as well on the geomagnetic disturbance level of the magnetospheric fields. This is expressed most simply through the well-known Kp geomagnetic indices. Obtaining a better understanding of the behavior of solar protons in their role as tracers should allow establishment of real-time predictive indices that will better define the state and expectation for the Earth's environment significant to man's activities.

Principles of Operation of the MEPED Sensor. The MEPED consists of four directional sensor systems, a pair that view the local zenith and a pair that "look" 90 degrees to this direction, as well as three omnidirectional sensors. Each pair of directional sensors consists of a proton telescope and an electron detector. The 90 degree sensors "look" nominally along the -Z axis in the spacecraft XZ plane. The viewing cone of these sensors is unobstructed by the sunshade.

Three further higher energy proton sensors in the MEPED use detectors in a dome moderator arrangement, in which the energy threshold is basically defined by the energy loss in the shielding moderator.

J. SOLAR BACKSCATTER ULTRAVIOLET INSTRUMENT (SBUV/2)

There has been much concern expressed in recent years about the effect of anthropogenic products on the stratospheric ozone layer's ability to shield the Earth from the sun's ultraviolet radiation. The release of chlorofluorocarbons into the atmosphere could affect the ozone amount in the stratosphere. This in turn could lead to changes in the atmosphere and at the surface of the Earth. Variations in atmospheric ozone can also result in changes in the radiative properties of the atmosphere, ultimately leading to changes in the Earth's climate.

In response to these concerns, Congress enacted Public Law 95-95, the Clear Air Act Amendments of 1977, requiring Federal agencies to undertake continuing studies of the effect of all substances, practices, processes, and activities that may affect the stratosphere, and especially ozone.

1. Scientific Rationale

The rationale for establishing a major program of stratospheric studies is based on the need to understand the responses of basic parameters of the atmosphere to perturbations caused by anthropogenic and natural influences. Initially, the distribution of the chemical constituents is governed by solar radiation and the natural sources of the constituents interacting through photochemistry. The heating associated with the solar radiation influences the temperature, which, in turn, influences the distribution due to temperature-dependent chemical reaction rates, and the redistribution of material by winds. In order to understand the causes of observed change in the constituents, information is needed on all the other aspects as well. The monitoring of ozone by satellite methods is but one aspect of the overall global monitoring of the upper atmosphere.

Current photochemical models of upper atmospheric ozone changes due tothe action of fluorocarbons predict a change in ozone of about -0.4 percent per year at altitudes around 40 km. (The change is significantly less above and below this altitude.) This change is superimposed on the natural variability that arises from such causes as meteorologically connected oscillations and solar variations. It has been determined that in order to isolate the linear trend due to anthropogenic perturbations, long-term measurements should be capable of detecting a 0.1 percent per year change over a 10-year period. In order to detect these predicted ozone trends, stringent requirements are placed on the observational capabilities. Knowledge of the variability of the solar flux also will be essential in order to associate observed changes in upper atmospheric ozone with this cause.

For its part, NOAA has established a continuing program of research and monitoring of the stratosphere from satellite platforms for the early detection of stratospheric changes and the climatic effects of such changes. NOAA has selected the solar backscatter ultraviolet instruments (SBUV/2) (a derivative of the NASA BUV and SBUV instruments flown on Nimbus 4 and 7, respectively) as the primary operational instrument to monitor ozone. The SBUV/2 was chosen because of the precision and reliability of the previous SBUV and BUV instruments on the Nimbus satellites, which demonstrated that the necessary measurements could be made from space, utilizing this technology.

2. Instrument System

The SBUV/2 is an operational remote sensor designed to make measurements that will allow the mapping, on a global scale, of total ozone concentrations, and the vertical distribution of ozone in the Earth's atmosphere up to about 55 km height. The purpose of the SBUV/2 instrument is to provide data to be used for the detection of ozone change, and to distinguish between natural and manmade causes of atmospheric ozone change.

The SBUV/2 instruments on the NOAA environmental satellites are designed to provide measurements that will permit determination of the total ozone in a vertical column beneath the satellite, and its distribution with height in the upper atmosphere. The SBUV/2 contains a double monochromator designed to scan through the ultraviolet spectrum measuring spectral intensities. In its primary mode of operation, the monochromator measures solar radiation backscattered by the atmosphere in discrete wavelength bands in the near ultraviolet, ranging from 252.0 to 339.8 nm. The retrieval algorithm for total ozone amount uses the longest wavelength bands, whereas the algorithm for vertical profiles uses the shorter wavelengths. The SBUV/2 also makes periodic measurements of the solar flux by deploying a diffuser plate into the field of view of the instrument to reflect sunlight into the instrument.

The instrument is mounted so that it looks in the nadir direction. As the satellite moves in a sun-synchronous orbit, the field of view traces 160 km wide paths on the ground. The Earth rotates approximately 265 degrees during each orbit. The satellite footprint moves at a speed of about 6 km/s. In the operational mode, a set of 12 measurements needed to obtain a separate vertical profile is taken every 32 seconds.

The SBUV/2 instrument also measures the solar irradiance with a continuous spectral scan in order to obtain solar information used in the retrieval process, as well as for obtaining basic data on the sun itself.

3. Theoretical Foundations

The ultraviolet radiation received at the satellite in the total ozone bands consists mainly of solar radiation that has penetrated through the stratosphere and has been reflected back by the dense tropospheric air and the Earth's surface. Ozone, being concentrated in the stratosphere above the region in which most of the radiation is scattered, acts as an attenuator of this radiation. By determining the amount of attenuation in the ozone absorption band, the amount of ozone above the reflecting surface can be accurately estimated. More than 90 percent of the ozone is located above the tropopause, and all clouds, most of the aerosols, and approximately 80 percent of the atmosphere are located beneath it. This almost complete separation of the ozone from the scatterers and reflectors minimizes errors caused by vertical profile shape, clouds, aerosols, and other tropospheric variables. Because of the greater sensitivity to ozone absorption at the shorter wavelengths, these are used to determine vertical profiles.

4. Operational Phases

The SBUV/2 has five instrument operation modes and five scene observation modes.

The instrument operation modes are:

- Discrete Mode. The instrument is stepped through each of 12 discrete wavelength positions used for retrieving ozone data and dwells at each position for 1.25 seconds. The 12 discrete wavelengths are covered in 24 seconds.
- Sweep Mode. The instrument is continuously swept through the wavelength range of 400 to 160 nmi.
- Wavelength Calibration Mode. The instrument is stepped through 12 discrete positions around the 253.7 nm spectral line emitted by the mercury calibration lamp onboard.
- Position Mode. The instrument is moved to and stopped

at a specific wavelength. It will stay in this position until commanded to another position or into another mode.

- Stop Mode. All movement is stopped.

The five scene observation modes are:

- Earth View Mode. The diffuser remains stowed and the calibration lamp assembly is deployed to the open position. The monochromator can operate in either discrete or sweep mode.

- Sun View Mode. The diffuser is deployed to view the sun, and sunlight is reflected into the instrument during a portion of each orbit. The monochromator operates in either the discrete or sweep mode.

- Wavelength Calibration Mode. The diffuser is directly in front of the instrument aperture and the wavelength calibration lamp covers both apertures.

- Diffuser Check Mode. In this mode, the instrument views the diffuser illuminated by the wavelength calibration lamp. The monochromator scans the same spectral lines as in the wavelength calibration mode. The ratio of the two sets of data (lamp directly and lamp reflected from diffuser) provides a check of the diffuser spectral reflectivity.

- Diffuser Decontamination Mode. The diffuser is pointed away from the instrument and a heater is turned on, heating the diffuser, thus decontaminating the surface.

5. Applications

The SBUV/2 will produce ozone total amount and vertical profile measurements globally on a daily basis. When combined with the ground-based monitoring and validation program, it is hoped a better understanding and more information on ozone will be obtained. The primary goals of this combined endeavor are:

- Acquire, process, and evaluate various atmospheric data necessary to detect how the parameters that may impact atmospheric ozone are changing.

- Improve understanding of the natural global variability of total atmospheric ozone and its vertical distribution with time. This information is essential to detect any trend change exceeding, in a statistically significant sense, the limits of natural variability.

- Provide sufficient information and data in standardized form to numerical modelers to test and validate the models that are used to predict potentially harmful impacts from such changes.

- Provide validated data to national and international agencies so that recommendations for remedial actions can be established. These data will be available in the formats shown in table VI-9, starting in late 1985.

Table VI-9
SBUV/2 Ozone Products

Product Description	Precision	Spatial Resolution	Geographic Coverage	Output Format
Level ozone 40, 30, 20, 15, 10, 7, 5, 4, 3, 2, 1.5, 1, .7, .5, .4, .3 mbar	±5%	200 km	Global	Computer disk 5-day rotating file, archive tapes
Layer ozone 500-250, 250-125, 125-62.5, 62.5-31.2, 31.2-15.6, 15.6-7.8,7.8-3.9, 3.9-1.96,1.96-.98, .98-.49,.49-.24, .24-0 mbar	±5%	200 km	Global	Computer disk 5-day rotating file, archive tapes
Total ozone	±1%	200 km	Global	Computer disk 5-day rotating file, archive tapes
Global averaged total ozone	±5 Dobson units	-	Global	Printed reports, archive tapes

K. ARGOS DATA COLLECTION AND LOCATION SYSTEM (DCLS)

The Argos data collection and location services system (DCLS) was designed to provide an operational environmental satellite data collection, location, and dissemination service for the duration of the NOAA TIROS-N program. This system resulted from a 1974 agreement among NASA and NOAA of the United States, and the Centre National d'Etudes Spatiales (CNES) of France. The Argos DCLS, as it exists today, has been fully operational since 1979.

The Argos DCLS instrument has flown onboard all of NOAA's TIROS-N series polar-orbiting spacecraft, beginning with the TIROS-N prototype. CNES plans DCLS instruments for all NOAA spacecraft through NOAA M (to the mid-1990's).

The Argos DCLS is administered by Service Argos, a department of CNES, and is headquartered in Toulouse, France, at 18 Avenue Edouard Belin, 31055, Toulouse CEDEX.

1. Monitoring

The Argos DCLS operation is monitored by the Argos Operations Committee, a bilateral (France/U.S.) oversight organization made up of representatives of the three participating agencies (NASA, NOAA, and CNES). The committee is cochaired by CNES and NOAA. The Operations Committee is responsible for ensuring that the system is operated according to the Memorandum of Understanding (MOU).

The Argos DCLS is reserved for the collection of environmental data, defined as measurements of physical, chemical, or biological properties of solid Earth, Earth's waters (rivers, lakes, and oceans), and the atmosphere (including space). Programs not directly concerned with the environment may, in exceptional cases, be approved by the Operations Committee provided that the program lasts no more than 6 months.

The data processing center in Toulouse is responsible for Argos system integrity, and performs extensive operational monitoring of the system from data received in the processing center.

2. Argos Subsystems

The Argos DCLS is composed of four subsystems:

- The user platform transmitter terminals (PTTs), mounted on buoys, balloons, animals, ships, or land-based stations. The PTTs can be obtained from any manufacturer, but must be type-certified by Service Argos.

- The onboard equipment package included in the payload of the NOAA TIROS-N series of satellites.

- NOAA's telemetry data receiving systems, the communication network, and the data processing center at Toulouse.

- The data distribution system (also located at Toulouse), which distributes results to system users.

a. Platform Transmitter Terminals. There are two basic categories of PTT: location type, equipped with good quality oscillators used for both location and data collection, and data collection only type, which may be equipped with lower quality oscillators. The characteristics of Argos PTTs are summarized as follows, and in table VI-10.

- Uplink transmission frequency: 401.650 MHz. This frequency band is reserved for environmental programs accepted by the joint NOAA-NASA-CNES Argos Operations Committee.

- Message repetition period (i.e., interval between successive transmitted messages): 40 to 60 s for location-type PTTs, 100 to 200 s for data collection only PTTs.

- Message length and data rate: 32 to 256 bits at 400 bits per second.

- Mean power (RF output) requirement: approximately 200 mw.

The accuracy of PTT positions obtained from the Argos DCLS depends on the stability of the transmitter oscillator, but is usually better than 1 km with currently available commercial transmitters.

b. Onboard Equipment. The space segment of the Argos DCLS consists of appropriate equipment onboard two NOAA satellites in polar orbits. Onboard data recovery units receive messages transmitted by PTTs within the satellite's area of coverage, approximately a 5,000 km circle (fig. VI-6). Processing performed by the onboard equipment consists of the identification of the PTT, the recording of the time of reception of data contained in the message, and the measurement of the Doppler shift on the received signal. Since there are normally two satellites in operation, a minimum of six positions per day are obtained from a PTT near the Equator and up to 28 positions per day are obtained in polar areas. In temperate latitudes, eight positions per day typically are provided (table VI-11).

The Argos DCLS data are available from the satellites in three modes:

- The S-band, which plays back the recorded TIROS TIP data on 1698, 1702.5, or 1707 MHz at 2.66 mbps

- The real-time S-band on 1698 or 1707 MHz at 665.4 kbps

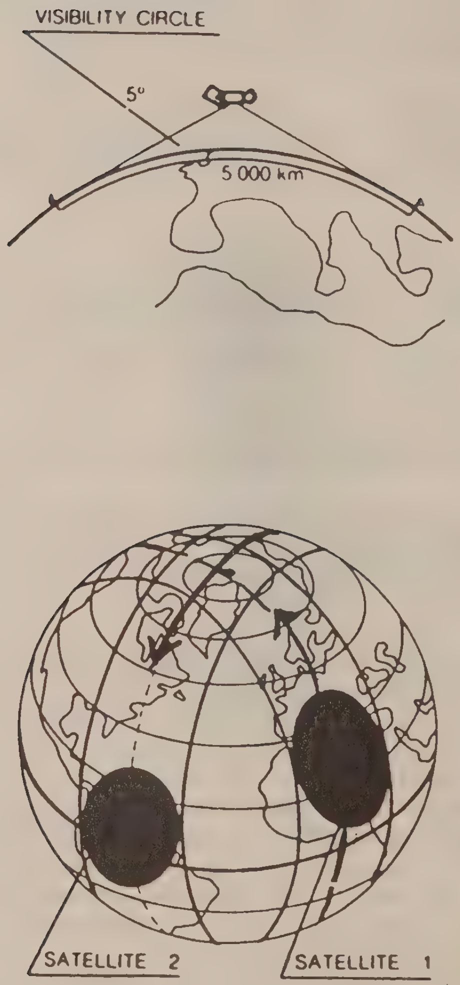

VISIBILITY CIRCLE
5°
5 000 km
SATELLITE 2
SATELLITE 1

Figure VI-6
Area of Satellite Coverage

Table VI-10
Argos Platform Characteristics

Carrier frequency	401.650 MHz
Aging (during life)	± 2 KHz
Short-term stability (100 ms)	$1:10^9$ (platform requiring location) $1:10^8$ (platform not requiring location)
Medium-term stability (20 min)	:0.2 Hz/min (requiring location)
Long-term (2 hours)	:±400Hz
Power out	34.8 dBm (3W)nominal
Range during transmission (stability)	:0.5 db
Antenna	Vertical linear polarization
Message length	360 ms to 920 ms
Repetition period for message	40- 60 s (requiring location) 60-200 s (not requiring location)
Data sensors	4-32 8-bit sensors for environmental data
Total number of platforms	4,000 global 459 within view

(From Argos User's Guide, May 1984)

- The real-time VHF beacon on 136.77 or 137.77 MHz at 8.32 kbps

c. Ground Reception and Processing. Each time a satellite passes over one of the three telemetry receiving stations (Wallops, Virginia; Gilmore, Alaska; Lannion, France), all the recorded TIP data are transmitted to that station as shown in figure VI-7. All Argos data received from these receiving stations are then sent, via the NOAA/NESDIS facility in Suitland, Maryland, to the Argos Data Processing Center in Toulouse, where the following processing operations are performed:

TABLE VI-11
ARGOS PASS FREQUENCY AND DURATION

PTT Latitude	Cumulative Coverage over 24 Hours (minutes)	Min. Number of Passes per 24 Hours	Mean Number of Passes per 24 Hours	Max. Number of Passes per 24 Hours
0°	80	6	7	8
± 15°	88	8	8	9
± 30°	100	8	9	12
± 45°	128	10	11	12
± 55°	170	16	16	18
± 65°	246	21	22	23
± 75°	322	28	28	28
± 90°	384	28	28	28

Sidelap increases with latitude. The number of daily passes over a given Platform Transmitter Terminal (PTT) also depends on latitude. At the poles, the satellites see all PTTs each at every pass, that is, 28 times a day in total. Pass duration, however, is independent of site latitude. The normal cutoff point for estimating pass duration is an elevation of 5 degrees above the horizon. The mean duration for pass is about 10 minutes, while that of zenith pass is 13 minutes.

The most significant pass characteristics are shown above. The figures relate to both satellites, but in the event of a PTT being seen simultaneously (high latitudes), only one pass is taken into account.

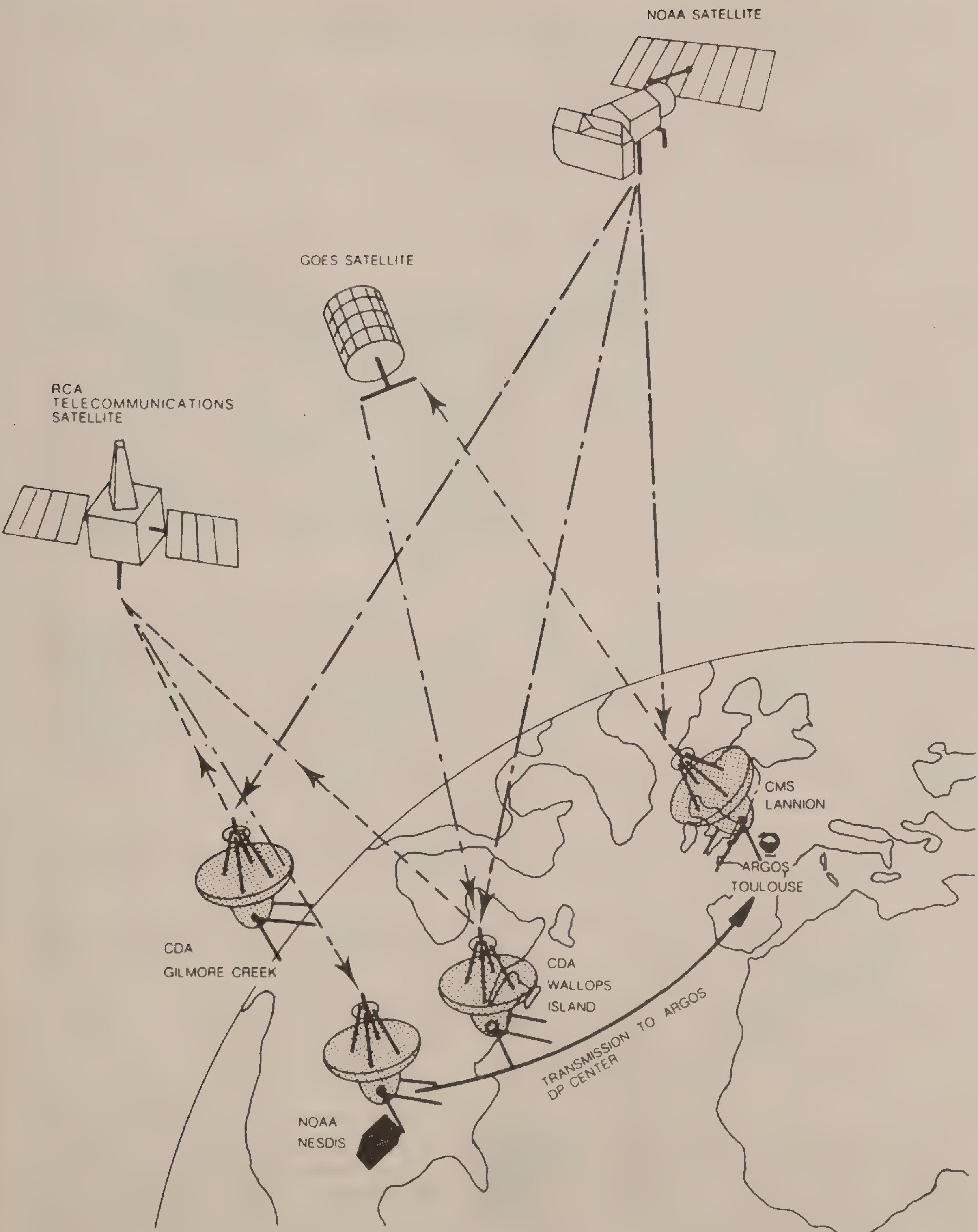

NOAA SATELLITE
GOES SATELLITE
RCA TELECOMMUNICATIONS SATELLITE
CMS LANNION
ARGOS TOULOUSE
CDA GILMORE CREEK
CDA WALLOPS ISLAND
TRANSMISSION TO ARGOS DP CENTER
NOAA NESDIS

Figure VI-7
Argos Telemetry Ground Stations

- Decoding of the received PTT messages and conversion of data into physical units

- Very accurate computation of the satellite orbits

- Computation of PTT positions from orbital data and Doppler shifts

- Storage of all these results on computer files for user access

Users requiring real-time data can also acquire these data directly from the satellite through reception of the HRPT S-band downlink or VHF beacon. Since each transmission is rebroadcast by the satellite as soon as it is received, anyone with a downlink receiver within range of the satellite can receive data from PTTs in view of the satellite at the same time. Such receivers, or local user terminals (LUTs), are already being operated by some agencies, and one is also operated in Toulouse by Service Argos. Although positions can be determined from the information received by a LUT, the accuracies achieved so far are measured in tens of kilometers, principally due to software limitations.

d. Data Distribution. There are several ways in which data collected by the Argos DCLS may be obtained from Service Argos. They are available on computer files accessible by telephone, telex, or communication networks, generally within 4 hours after the receipt of data from the satellite. Processed data can also be made available on computer-compatible tapes (CCTs) or printouts, either fortnightly or monthly. Data appropriately formatted may be distributed over the GTS. The user can access three types of files (fig. VI-8):

- The "AJOUR" file, containing the most recent location and sensor message for each PTT

- The "Telex" file, containing, in chronological order, one sensor message and corresponding location per satellite pass for each PTT

- The "DISPOSE" file, containing, in chronological order, all location data and all sensor messages for each satellite pass, and each PTT

Service Argos is operated on a cost-recovery basis, with users contributing a fraction of the operating costs proportional to the amount of service required. Government users from the same country can reduce their financial contribution by jointly signing a "global contract." Services not covered by a global contract are ordered separately from Service Argos by each user.

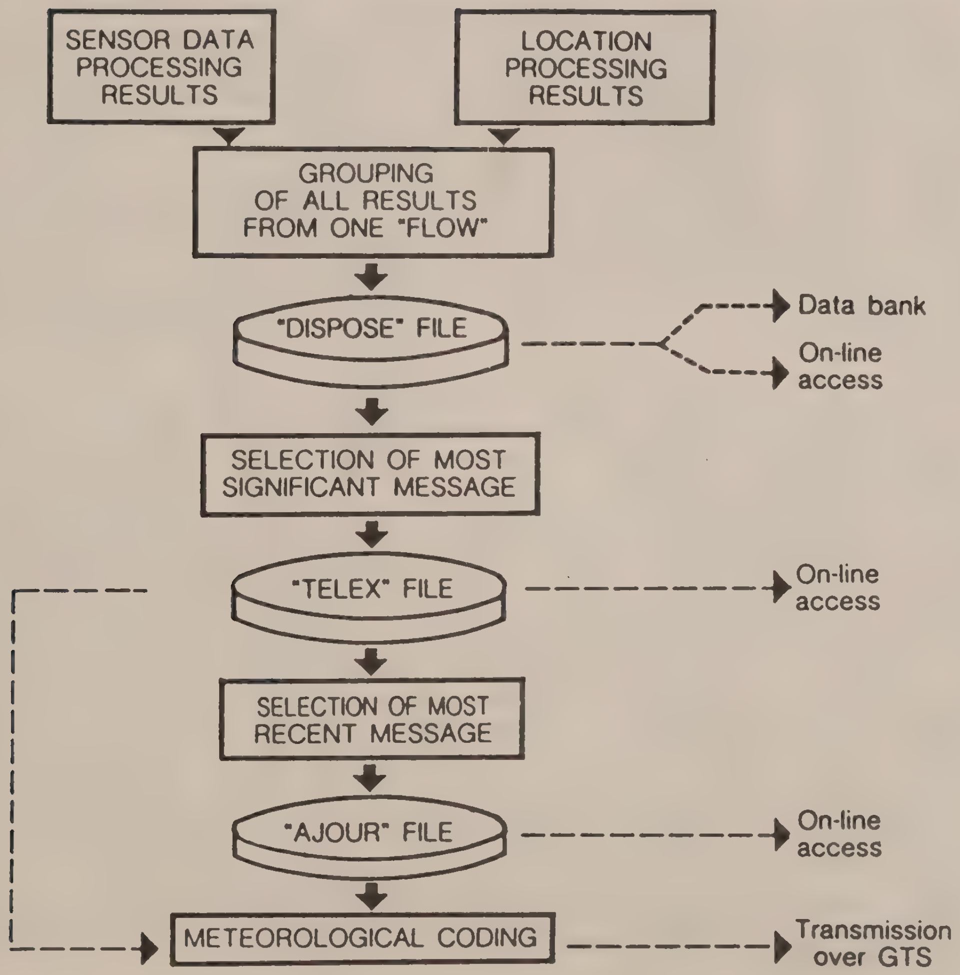

SENSOR DATA PROCESSING RESULTS
LOCATION PROCESSING RESULTS
GROUPING OF ALL RESULTS FROM ONE "FLOW"
"DISPOSE" FILE
Data bank
On-line access
SELECTION OF MOST SIGNIFICANT MESSAGE
"TELEX" FILE
On-line access
SELECTION OF MOST RECENT MESSAGE
"AJOUR" FILE
On-line access
METEOROLOGICAL CODING
Transmission over GTS

Figure VI-8
File Creation

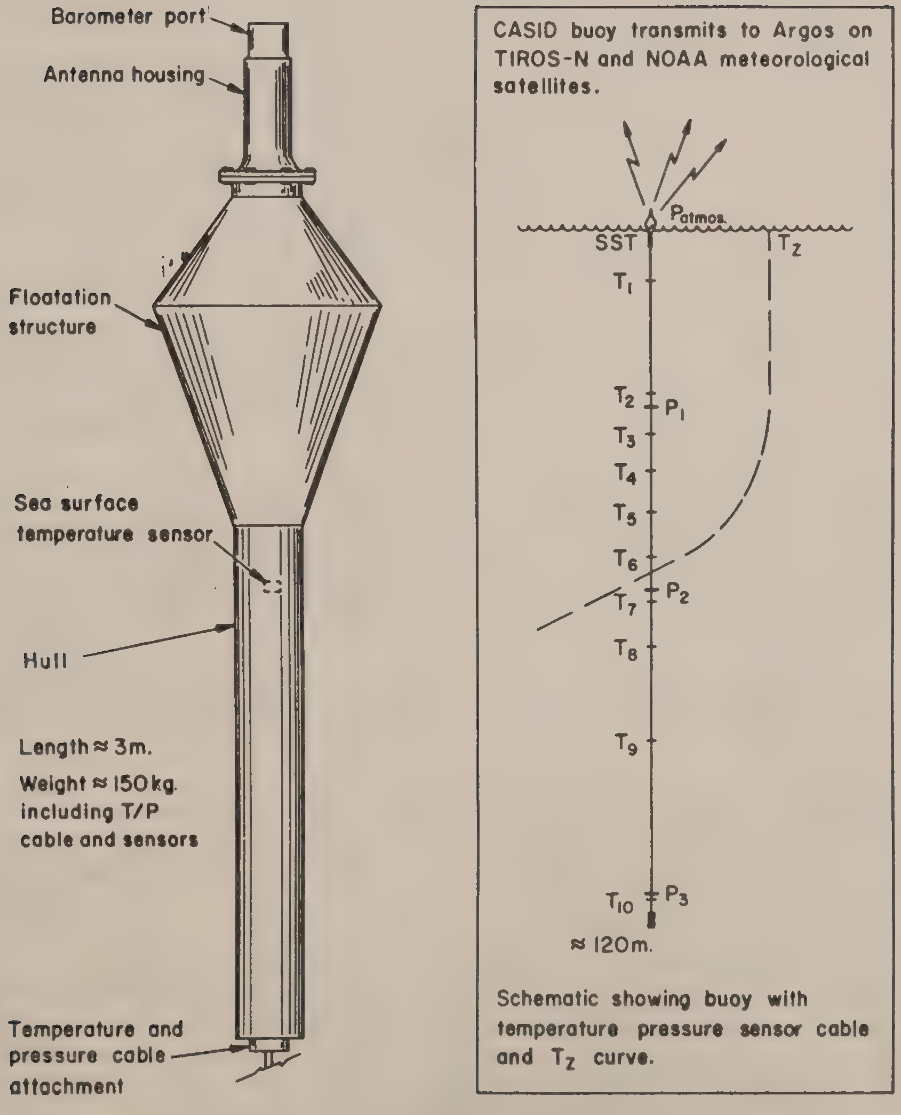
3. Argos System Applications

Applications cover a wide range of environmental studies of the sea, land, and air, as well as biological research (birds, animals, mammals). Two of the newest applications, which are not yet well documented, involve work in glaciology and volcanology. Some of the more extensive applications are described in the following subsections.

a. Drifting Buoys. Drift bottles have been used for centuries both as a curiosity of sending a message by the sea, sometimes in distress, and as a means of crudely tracking ocean surface currents. A variation of the drift bottle, or drifting buoy experiment, was in existence off the east coast of the United States in the 1920's and 1930's (Bumpus and Lauzier, 1965). This period of coastal drift bottle operations coincided with the era of Prohibition, when illicitly imported whiskey was floated ashore. These drift bottle experiments became noticeably less popular after the repeal of Prohibition; however, they did add to the knowledge of coastal currents.

In the last three decades, sophisticated means of tracking ocean platforms have been developed using optics, radar, direction-finding radar, and acoustical techniques for tracking constant level floats at various depths in the ocean. These methods are now complementary to the location and data collection capability of the low-orbiting meteorological satellite. The 1979 Global Weather Experiment included an array of more than 300 drifting buoys in the oceans of the Southern Hemisphere (Fleming, et al., 1979). These buoys were monitored by the Argos system on the polar-orbiting TIROS-N series spacecraft. Service Argos collected and processed these data randomly transmitted from the drifting buoys, producing buoy positions, atmospheric pressure, and sea surface temperature. The Southern Hemisphere drifting buoy experiment was one of the most successful of the Global Weather Experiments. It was productive in providing in situ operational meteorological data to the national weather services of the Southern Hemisphere, as well as providing crucial research data for the Global Atmospheric Research Program.

The Climate Air-Sea Interactive Drifter (CASID) buoy was developed by scientists and engineers as a system tool to investigate the processes that determine the thermal structure of the upper ocean (McWilliams and Masterson, 1982). The CASID buoy (fig. VI-9) has undergone three phases of progressive development, from CASID-I, which measured temperatures through the upper ocean mixed layer to a depth of about 100 m, sea surface temperature, and atmospheric pressure, to the third generation CASID-III (Large, et al., 1982). In addition


Barometer port
Antenna housing
Floatation structure
Sea surface temperature sensor
Hull
Length ≈ 3m.
Weight ≈ 150 kg. including T/P cable and sensors
Temperature and pressure cable attachment
P atmos.
SST
T_Z
T_1
T_2
P_1
T_3
T_4
T_5
T_6
P_2
T_7
T_8
T_9
T_{10}
P_3
≈ 120m.

CASID buoy transmits to Argos on TIROS-N and NOAA meteorological satellites.

Schematic showing buoy with temperature pressure sensor cable and T_Z curve.

Figure VI-9
Sketch of Casid Buoy

to meteorological sensors measuring the variables of pressure, temperature, and wind velocity, there is being evaluated a means to derive wind speed from the ambient acoustic noise at 4.3, 8.0, and 14.5 kHz, obtained from a hydrophone attached to the CASID thermistor line at 120 m depth.

In the 1985 to 1995 decade, there will be extensive experiments investigating the atmospheric-ocean interaction on an oceanic as well as a global scale. Among the experiments are the Tropical Ocean Global Atmosphere (TOGA) and the World Ocean Climate Experiment (WOCE). These national and international experiments will use polar-orbiting satellites to locate and receive data from large numbers of expendable drifting buoys deployed from research ships, ships of opportunity, and aircraft. These buoys will vary in measurement capability from sensing variables to determine atmospheric oceanic flux to simple, low-cost, Lagrangian drifters measuring surface currents (Heinmiller, et al., 1984).

In the meantime, the operational use of drifting buoys for both meteorology and oceanography will continue to be developed by NWS. These operational buoys will produce data to be used by national meteorological forecast services, and to establish a substantial data bank for research investigations.

Meteorological satellites, with systems like Argos and drifting buoys, form a powerful tool to observe the behavior of the atmosphere and the ocean. The next decade will provide more experiments and technological developments in observing and understanding the behavior of the atmosphere and the ocean. This information will assist in providing solutions to both synoptic and climatic problems. Measuring surface wind velocity using ambient noise is an imaginative development that illustrates the sensor opportunities for the drifting buoy.

The use of solar cells to prolong the energy life of the drifting buoy is being explored. Advances in microprocessing of data aboard the buoy, as well as improvements in data handling and distribution, will produce a viable and useful system for the measurement and use of meteorological and oceanographic data. Although relatively expensive in the moderately low volume use of today, with the expansion of operational buoy arrays and implementation of oceanwide research investigations, i.e., TOGA and WOCE, the relative cost of this valuable tool will decrease. In the 1990's the use of satellite-tracked drifting buoys will be routine for operations as well as research investigations.

b. International Ice Patrol. The Coast Guard has used data from DCLSs for operations and research beginning with the Nimbus-6 random access measurement system, and continuing with the present Argos DCLS. The Coast Guard's International Ice Patrol first deployed a drogued, satellite-tracked drifting buoy in the Labrador Current in April 1976 to obtain surface current velocities used in predicting iceberg drift trajectories (Weir, 1978). Since then, the International Ice Patrol has incorporated this method of obtaining direct current measurements into its operational routine, and has devised a sophisticated scheme for blending the drifting buoy measurements from the Argos DCLS with a 60-odd year historical geostrophic current field (Summy and Anderson, 1983).

In the interim, operational application of DCLS technology has been demonstrated for:

- Iceberg tracking (Robe, Maier, and Russell, 1980)
- Oil spill monitoring (Mountain, Murray, and Mooney, 1980)
- Search and rescue datum marker buoy project (Hayes, 1981)
- Foreign fishing vessel transmitting terminal project (Hayes and Murray, 1982)

Introduction of a prototype direct readout station, i.e., a LUT, in 1978 at the Oceanographic Unit in Washington, D.C., provided a low-cost alternative for receiving and processing DCLS data in near real time for the western North Atlantic Ocean and Gulf of Mexico. The LUT can automatically receive data from Argos PTTs whenever they are within an approximately 2,000 nmi radius of the receiving site, presently located in Miami, Florida.

Also, drifting buoys with Argos PTTs have been used by Coast Guard oceanographers for research in the study of ice drift and currents in the southern Beaufort Sea, to model potential oil spill trajectories, as targets and drift measurement devices in search and rescue "probability of detection" (of distressed persons or craft) projects, and to investigate the effect of wind persistence on near-surface currents in the Caribbean.

c. Ship Observation. The Scripps Institution of Oceanography (SIO) and the French Office de la Recherche Scientifique et Technique Outre Mer (ORSTOM) jointly use a network of commercial ships that voluntarily take oceanographic observations in the Pacific. The principal instrument used in this program is the expendable bathythermograph (XBT). The individual XBT is a small, disposable probe that is thrown from a ship and allowed to fall freely through the water. The temperature sensed by the probe is transmitted back to the ship via a fine wire, which breaks loose when the probe reaches 400 to 500 m depth. About half of the ships in the SIO/ORSTOM network are equipped with microcomputer-based systems that digitize the temperature versus depth "trace" and record it on tape cassettes. The particular XBT data processing and recording system employed is the one designed by the Technical Planning and Development Group at Oregon State University (OSU) (Mesecar and Wagner, 1979).

Shipboard microcomputers also prepare and display a summary of the trace in the standard World Meteorological Organization "bathymessage" format. Standard operating procedure for each of the volunteer ships requests that the ship's officers manually transcribe the bathymessage from the screen of the microcomputer and give the message to the ship's radio operator for transmission to designated shore stations in a manner similar to that used for conventional marine weather observations. The shore stations then place the bathymessage on the GTS.

The above process for getting XBT data into the GTS is inconvenient, inefficient, and prone to errors. In order to solve this transmission problem, OSU enhanced the basic XBT system by incorporating a Handar-type 621 Argos PTT (Mesecar and Wagner, 1982). In the spring of 1982, the first of these enhanced systems was placed aboard the 700 ft container ship M/V Lillooet, which operates between Australia and the west coast of the United States. The system has been automatically transmitting XBT bathymessages and ship position information from that time to the present, with only relatively few problems. More recently, SIO has tested the prototype of a Polar Research Laboratories (PRL) Argos transmitter, which accepts bathymessages from the computer via a serial, asynchronous RS-232 interface. The PRL unit stores the message in a buffer and retransmits it at 60 s intervals without further action by the computer.

The use of the Argos DCLS for transmitting XBT data has several advantages and disadvantages. The principal advantage is the ready availability of ship position. Other XBT satellite communications systems now in service depend upon manual entry of position by the ships' officers. In the future, systems without inherent position-fixing capability will probably incorporate some hard-wire connection to the host ship's own satellite navigation system. This connection will provide position information, but will increase the cost and complexity of the hardware required, create the risk of damaging the host ship's equipment, and possibly interfere with the operation of the ship. This is a very sensitive issue when dealing with volunteer commercial ships.

XBTs are dropped on a schedule, usually one drop every 6 or 12 hours, which is independent of the transit times of the receiving satellites. This means that the ship's positions reported by the Argos DCLS do not usually coincide with the ship's position at the time of the XBT drops. The actual drop positions must be approximated by extrapolation or interpolation. This procedure is not a serious source of error, since commercial ships in the open ocean travel along constant headings and at constant speeds for periods of time longer than the mean time between valid fixes. About one-half of the local satellite transits appear to result in valid fixes. Several-hour separations between the times of position fixes and the times of XBT drops would be a more serious problem if the volunteer ships were other than commercial vessels operating on preset routes.

A present impediment to the easy transfer of XBT data from ships to the GTS is the lack of a facility that will routinely interpolate position fixes to determine XBT drop locations, and also perform first-order quality control procedures on the temperature/depth data.

The inherent intermittency of data transmission opportunities using the Argos DCLS does not unduly restrict or delay the collection and effective use of XBT data. A brief study indicated that, with two satellites operating, and with the Lillooet crossing the mid-tropical Pacific, the bathymessages from most 6 hourly XBT drops were received on one or more satellite transits. Almost all of the local satellite transits result in the reception of 3 to 10 identical, and therefore valid, bathymessages at 60 s intervals.

The typical several-hour delay in the availability of the XBT data transmitted via the Argos DCLS is not an important factor in monitoring large-scale fluctuations in the oceanic thermal field. Large-scale fluctuations have temporal scales of weeks to months, so a 4 to 6 hour delay is hardly significant. High-frequency variations in the thermal structure do occur, but the volunteer ship XBT network cannot expect to map these fluctuations under any realistic conditions.

The present small data capacity of Argos is a handicap, but it must be admitted that very little effort has been expended to optimize the packing of temperature/depth profile information. The present OSU/Argos bathymessage is organized following WMO conventions into a series of five-number blocks that are easy to code and to read. The OSU approach uses 16 data bits to represent each five-number block. The 256 total data bits usually allow for 10 to 11 temperature/depth pairs. While 10 to 11 points are sufficient to characterize the general features of an XBT trace, they are far short of what could be accomplished by optimal computer coding and decoding of the original information.

d. Tracking Superpressure Balloons. The Argos DCLS has been an essential system for the location of superpressure balloons as they circle the globe, and for the relay of scientific data from the balloons' location at any point on Earth. Two major programs in recent years, the Tropical Constant Level Balloon System (TCLBS) and the Electrodynamics of the Middle Atmosphere (EMA), would not have been feasible without this capability.

Since 1978, the Argos DCLS has been used to locate and collect atmospheric data from superpressure balloons. During the Global Weather Experiment, 313 balloons were launched from tropical island sites and floated at an altitude of 14 km. The balloons circled the Earth, and their trajectories provided information on winds and temperatures at the top of the tropical troposphere. These data were not available by any other technique, since the balloons were flying above aircraft altitudes and the windfield cannot be computed from radiance measurements at tropical latitudes. The Argos DCLS averaged four locations for wind computations per day for each of the 313 balloon platforms. Average dwell time of the balloons at tropical latitudes was 60 days, providing an incomparable archive of critical data during the Global Weather Experiment.

The primary objective of the TCLBS program was obtaining wind and temperature data in areas inaccessible to other technologies. The EMA program was designed to provide information on a global scale of the variations of the Earth's electrical and magnetic fields, and their relationship to variations in electrical conductivity and other atmospheric phenomena. Since the satellite overpasses permitted data telemetry for only 10 to 15 minutes out of each 90 minutes, the scientific data were stored between overpasses by use of multiple ID codes. It was possible to provide continuous data on over 20 parameters for each of the balloon flights. The techniques demonstrated on this EMA program will be used in future programs, where the unique capabilities of superpressure balloons will be integrated with the globe-girdling coverage of the Argos DCLS.

e. Surface Weather Observations in Antarctica. The automatic weather stations (AWS) used for surface weather observations in Antarctica measure wind speed and direction, air temperature, and atmospheric pressure at a nominal height of 3 meters. Data are transmitted every 200 seconds to the Argos DCLS. These data include five values of each item spaced 10 minutes apart, with updating every 10 minutes. Four AWS units are equipped to measure relative humidity and vertical temperature difference, transmitting the last update and two previous values 20 minutes apart.

Raw data are obtained at monthly intervals from Service Argos; the processing to scientific units is carried out at the

University of Wisconsin. These scientific data are available as a monthly summary of 3-hourly values for each AWS unit. The complete data set is available on magnetic tape. Ninety or more data points at 10 minute intervals are collected out of the possible 144 data points in a 24 hour period, when two satellites are operational. Less than 1 percent of these transmissions contain possible data errors but, as a result of three transmissions of identical data sets, the lost data are essentially zero.

The Argos DCLS real-time data are transmitted on the VHF beacon and over the HRPT S-band downlink of the polar-orbiting satellites. The U.S. Navy at McMurdo and Ross Island in Antarctica has two systems for direct readout. One uses the HRPT and the other the beacon transmission. These data are processed to scientific units automatically and used in weather forecasting for aircraft operations.

At present there are 20 AWS units deployed in Antarctica between the Antarctic Peninsula and Dumont d'Ruville, with 16 operational. Any needed maintenance and new installations are done during the austral summer.

f. Animal Tracking. Using satellites to monitor movements, physiological variables, mortality, and microclimate around animals can provide biologists and wildlife managers with a great deal of useful information. It has often been difficult for biologists to study the behavior of birds and mammals because the presence of the fieldworker can disrupt normal behavior. Also, many species occur in such remote areas, or move so rapidly and widely, that they cannot be observed regularly. In the early 1960's, radiotelemetry techniques began to be applied to a wide variety of wildlife and biological problems.

The use of satellites was envisioned by biologists from the outset of applying radiotelemetry to studies of wildlife. Some pioneering work was conducted with free-ranging elk. However, the size and weight of the early package, determined primarily by the power requirements for the Nimbus-3 and -4 satellites, prohibited widespread application of the transmitter. During the next decade, several attempts were made to develop smaller, satellite-compatible radio transmitters that could be used with a diversity of animal species. The technology devoted to emergency locator transmitters and to monitoring locations of weather balloons and buoys via satellites led to packages designed and successfully used to track movements of polar bears and sea turtles. The total package sizes remained large (5 kg), and the number of species with which they could be used was very limited.

By 1982, at least four groups had undertaken projects to design lighter PTTs, compatible with the Argos DCLS for monitoring movements of wildlife. Toyo Communications Equipment Co., Inc., produced a 500 g transmitter packaged specifically for use on marine mammals such as porpoises and dolphins. In 1983 PTTs designed by Telonics, Inc., were successfully tested on whales (Service Argos, 1984), and in 1984 on caribou. The April 1984 Argos newsletter also reported that zoologists from the University of Aberdeen, Scotland, have used PTTs to track basking sharks. The group from Scotland is also developing a PTT to be used on birds.

Migratory birds have always presented a challenge to biologists attempting to understand their behavior and ecology, and birds pose a real challenge to those attempting to develop a bird-borne PTT. To be applicable to studies of migration, avian biologists suggested the first transmitters should weigh less than 200 g and last at least 200 days (a migration cycle). To meet this challenge, the Applied Physics Laboratory (APL) of Johns Hopkins University designed circuitry that is powered by a combination of solar cells and rechargeable nickel cadmium batteries. Service Argos certified this circuitry in 1983, and the staff of the U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, tested these packages on captive and, subsequently, wild birds. The prototype 160 g PTTs have provided reliable (± 300 m to ± 5 km position error, mean = 1 km) information for several months on the locations of many species of birds. Sensing capabilities for physiological variables (e.g., heart rate, temperature) and microclimate (e.g., temperature, barometric pressure) can also be monitored by PTTs designed by APL. These developments now allow ecologists to conduct studies of the movements, survival, and some behaviors of many birds and other animals that had previously been precluded by cost or logistics.

L. SEARCH AND RESCUE SATELLITE-AIDED TRACKING (SARSAT)

The Search and Rescue Satellite-Aided Tracking program is a cooperative effort among the United States, France, and Canada to equip and fly instruments on NOAA's polar-orbiting meteorological satellites for the purpose of detecting and locating emergency beacons of downed aviators and mariners in distress. The SARSAT partners have been further joined by the U.S.S.R., which provides similarly equipped satellites. The U.S.S.R. portion of the program is COSPAS, an acronym for Space System for Search of Distressed Vessels. This joint program is known as COSPAS/SARSAT. A more detailed discussion of the international aspects of the program is contained in chapter VIII of this report.

1. System Concept

The concept of the COSPAS/SARSAT system is that low-altitude, polar-orbiting satellites will locate distress incidents using Doppler position fixing on the radio frequency emissions of emergency locator transmitter/emergency position-indicating radio beacons (ELT/EPIRBs). In addition to working with existing ELT/EPIRBs at 121.5 MHz (and 243 MHz, in the case of SARSAT), the system is investigating operations with experimental ELT/EPIRB test units, operating in the assigned emergency band at 406 MHz.

The COSPAS/SARSAT system is composed of three main subsystems: the ELT/EPIRB, the spaceborne repeater/processor, and the ground receiver/processor. These subsystems are used to implement two data systems and two coverage models for the detection and location of ELT/EPIRBs operating in the three frequency bands. The two data systems are the repeater data system and the processed data system.

a. Repeater Data System. In the SARSAT system, a repeater onboard the spacecraft relays the 121.5/243 and 406 MHz signals directly to a LUT. Special processing is used at the LUT to extract the weak 121.5/243 MHz signals from the noise, recover the Doppler information, and determine the ELT/EPIRB position. The 406 MHz ELT/EPIRB test unit signals are handled in the same way, except that the signal strength and format are designed to permit the use of less sophisticated processing techniques. The COSPAS system does not relay the 243 MHz signals.

b. Processed Data System. Both the COSPAS and SARSAT spacecraft include 406 MHz data processors. The 406 MHz ELT/EPIRB signals are received, detected, and identified. The Doppler frequency is measured, and the ELT/EPIRB identification and status data are recovered. This information is time tagged, formatted as digital data, and transferred to both the repeater downlink for real-time transmission to the LUT and to the spacecraft telemetry subsystem for storage and later transmission to the NOAA ground stations for SARSAT, and to any LUT for COSPAS.

A fundamental requirement imposed on the concept is that it work with existing ELT/EPIRBs operating at 121.5 and 243 MHz. Although not designed with satellite detection and location in mind, these devices are in widespread use, particularly in North America, and will continue to be used for many years.

Doppler positioning using the relative motion between the spacecraft and the ELT/EPIRB has been chosen as the only practical means of locating these very simple devices. All that is required of the ELT/EPIRB is that it emit a carrier frequency with a reasonable stability during the duration of visibility. Although the planned 406 MHz test units are more complex through the addition of identification and situation codes, retention of the Doppler-positioning concept allows for minimum complexity in the ELT/EPIRBs.

To optimize Doppler-positioning performance, a low-altitude polar orbit is used. The low altitude results in low ELT/EPIRB power requirements, good Doppler-shift characteristics, and short time delays between successive passes. The polar orbit results in coverage of the whole Earth.

2. Operating Characteristics

The two coverage modes are regional coverage and global coverage.

a. Regional Coverage Mode. This mode provides coverage to areas where the spacecraft is actually visible to an ELT/EPIRB and a LUT, an area approximately 4,000 km in diameter, centered on the LUT location. The 121.5/243 MHz and the 406 MHz distress signals are relayed in real time to the LUT. The LUT receives the ELT/EPIRB signals relayed by the satellite and computes the location of the beacons. The computed location data are then transmitted to the Mission Control Center (MCC), where they are sorted geographically and distributed to the appropriate Rescue Coordination Center (RCC).

In the regional mode of operation, the ELT/EPIRB signals are available only when both the ELT/EPIRB and the LUT are within the satellite field of view at the same time (mutually visible). During a satellite pass, the maximum available mutual visibility period (MVP) is approximately 15 minutes, but at least 4 minutes of mutual visibility are required to compute location.

b. Global Coverage. The SARSAT global mode operates only with the 406 MHz experimental ELT/EPIRBs. A 406 MHz distress signal detected anywhere on Earth is processed and stored as data onboard the satellite. When the satellite comes within the field of view of one of the NOAA Command and Data Acquisition (CDA) stations, located in Gilmore, Alaska, and Wallops, Virginia, the stored data are played back on command. The data are relayed to NOAA's processing facility in Suitland, Maryland, for further processing, and are transmitted to the USMCC at Scott Air Force Base, Illinois, where the location of the beacon is computed. The USMCC performs a geographic sort and distributes the information to the RCCs.

The COSPAS regional and global modes differ from SARSAT in that the COSPAS satellites relay the stored 406 MHz signals at the same time as the 121.5 MHz signals to the LUTs only. Also, COSPAS is not equipped to operate with 243 MHz beacon signals.

Frequency of coverage is dependent on the number of satellites in orbit. It is also latitude dependent, with more frequent coverage at higher latitudes. Assuming a single satellite, the maximum time between successive detections at the Equator is 12 hours. Increasing the number of satellites in the constellation to four decreases the mean wait time between passes to approximately 1 1/2 hours at mid-latitudes.

Accurate ELT/EPIRB location is dependent on the noise and interference background, the characteristics of the particular ELT/EPIRB, and the location relative to the satellite orbit. The system has demonstrated accuracies of 12 to 15 km for existing 121.5/243 MHz ELT/EPIRBs, and 2 to 5 km for the 406 MHz test units.

3. Space Segment

Under the conditions of the current MOU, the space segment calls for a constellation of four SAR packages in orbit through at least 1990, and allows for continuation beyond that into the indefinite future. The MOU contains agreements by the United States and the U.S.S.R. to each maintain two SAR-equipped spacecraft in orbit. The MOU specifically states, "After the launch of NOAA F and G, two SARSAT-equipped spacecraft will be maintained in orbit under normal operations."

The remainder of the NOAA satellites in the advanced TIROS-N series will be equipped with SARSAT instruments provided by Canada and France, offering full or partial coverage for the balance of the 1980's. In addition, SARSAT instruments are included as requirements for the next generation of NOAA polar-orbiting meteorological satellites, which NOAA is preparing to procure. NOAA expects that Canada and France will provide these instruments. The Soviet Union is planning to build additional satellites to provide two-satellite coverage through 1990 as well. Thus, current plans assure continued satellite coverage for at least the next 7 years.

SARSAT Equipment. The SARSAT equipment consists of five basic components: 121.5 MHz receiver, 243.0 MHz receiver, 406.05 MHz receiver, 406.025 MHz receiver/processor, and 1544.5 MHz transmitter. The spacecraft MIRP is used to frame the downlinked signal. Descriptions of the equipment and MIRP functions are as follows:

- 121.5 MHz Receiver. This unit is a double-conversion receiver, with a first intermediate frequency (IF) at the output frequency of 7.19 MHz, and a second IF at the output frequency of 47.0 kHz. The IF bandwidth is 25 kHz. It is a linear receiver, with an automatic level control (ALC) to maintain the output level constant to within

±0.5 dB. The output level to the transmitter phase modulator can be adjusted in several steps about the nominal level of .35 rad rms. A clipper is included to prevent the modulation index of the composite downlink from increasing beyond the 2.8 rad peak.

- 243.0 MHz Receiver. This unit is a double-conversion receiver with a first IF at the output frequency of 14.38 MHz and a second IF at the output frequency of 94.0 kHz. The IF bandwidth is 46 kHz. It is a linear receiver with an ALC to maintain the output level constant to within ±0.5 dB. The output level to the transmitter phase modulator can be adjusted in several steps about the nominal level of 0.35 rad rms. A clipper is included to prevent the modulation index of the composite downlink from increasing beyond the 2.8 rad peak.

- 406.05 MHz Receiver. This unit is also a double-conversion receiver, with a first IF of 24.05 MHz and a second IF at the output frequency of 170 kHz. The IF bandwidth is 80 kHz. It is a linear receiver, with an ALC to maintain output level constant to within D + 0.5 dB. This output to the transmitter phase modulator can be adjusted in several steps about the nominal level of .15 rad rms. A clipper also is provided to limit the peak phase modulation index of the downlink to the 2.8 rad peak.

- 406.025 MHz Receiver/Processor. This unit is a double-conversion receiver, with a first IF of 60.11 MHz and a second IF of 16.87 MHz. It is a fixed gain, linear receiver. The receiver output is fed to the signal acquisition unit of the processor, and when signals are detected the control logic assigns a data recovery unit (phase locked loop) to the signal. The data recovery unit locks onto the carrier, acquires bit and word synchronization, demodulates the data, measures the Doppler frequency, time tags the data, and outputs the data with the time tag to the MIRP. From the input through the signal demodulation, the entire implementation is in analog form.

- MIRP. This unit is part of the NOAA spacecraft. It formats the input data from the 406.025 MHz receiver/processor and stores it on the main spacecraft tape recorder for later playback to a NOAA ground station. It is not possible to dump the 406 MHz data directly to a LUT. The MIRP formats the data in real time to the proper downlink format, and provides the signal to the 1544.5 MHz transmitter.

- 1544.5 MHz Transmitter. This unit accepts inputs from the 121.5/243 MHz receivers, the 406.05 MHz receiver, and the MIRP, phase modulates the composite spectrum onto a low-frequency carrier, multiplies this frequency by 4 to 1544.5 MHz, amplifies the level to 8 W, and provides this signal to the downlink transmit antenna.

VII. ANALYSES OF ORBITAL REQUIREMENTS

A. TIMELINESS AND GEOGRAPHIC COVERAGE

In general, the utility of satellite data is directly proportional to the rapidity with which it is made available to the user. In the case of the geostationary satellite, where new views are available nominally every 30 minutes, and can be obtained in time intervals of less than 15 minutes, the utility of the data only exists if the delivery of the data to the user is nearly instantaneous. For the polar-orbiting satellites, the global data are available on an orbit-by-orbit basis about every 101 minutes. For the direct readout users, who can only acquire those orbits that are within line-of-sight view, data are available only several times each day. Thus, polar satellite turnaround constraints are less instantaneous and more fitting to the frequency of the orbits. However, for those orbits that provide coverage to the forecast models for fixed synoptic periods, timely processing is critical for those data collected within a rigid data time window in order to be made available in time for the model turnaround. The 101-minute in-orbit delay further erodes the available time left for processing.

Also, the orbit altitude and inclination are designed so the spacecraft orbits the Earth about the poles in a circular orbit. The plane of the orbit is inclined so that the flight of the spacecraft as it crosses the Equator is such that the sun's relative position to the Earth is always the same. This orbit, which the DMSP and POES satellites fly, is called a "sun-synchronous" orbit. This is a circular orbit about 850 km high and inclined about 98.9 degrees from the Equator, with the satellite heading in a westward direction as it crosses the Equator relative to a fixed sun time. It takes about 14.25 revolutions per day to provide complete global coverage. Each revolution around the Earth takes about 101 minutes.

1. DMSP

The timeliness, geographic coverage, repeat times, and nodal crossing times of DMSP satellites are dictated by a broad spectrum of requirements. They are based primarily on validated support to 1-1 Precedent programs. A principle military requirement is the ability to select specific and frequently different nodal crossing times and daylight ascending or descending orbits as driven by specific operational requirements at the time of launch. Numerical models at AFGWC are used to determine the optimum nodal crossing time based on a variety of strategic and tactical requirements. The orbits are selected to maximize the receipt of visible and infrared cloud cover imagery around the globe, the primary DOD requirement.

2. POES

The polar orbits are arranged to be either descending morning orbits (southbound crossing the Equator in the morning hours) or ascending afternoon orbits (northbound crossing the Equator in the afternoon).

The polar satellites are placed into specific orbits to provide optimum coverage to suit the intent of the mission. Early on, early morning and late afternoon orbits were arranged to optimize the viewing during maximum and minimum periods of meteorological activity. As quantitative satellite data, especially soundings, became more widely accepted as input to numerical forecasts, orbit times were set to be more compatible with the product delivery requirements. As a result, starting with the NOAA H polar-orbiting satellite, the sun shields will be fabricated to allow an orbit earlier in the afternoon than the previous satellites in an effort to meet the time and geographic coverage necessary to the input needs of the National Meteorological Center (NMC) forecast models. (See chapter III for a detailed description of the changes in the spacecraft.)

B. INPUT TO ANALYSIS/FORECAST MODELS

1. DMSP

a. OLS. These data are input into the satellite global data base with a resolution of 3 nmi, and are used in the real-time nephanalysis (RTNEPH) and the AFGWC cloud analysis model, with a resolution of 25 nmi. The RTNEPH initializes two cloud forecast models--the high-resolution cloud prog, which makes forecasts of clouds out to 9 hours at 25 nmi resolution, and the five-layer cloud forecast model, which makes forecasts of clouds out to 48 hours at 100 nmi resolution (chapter IV, section A).

b. SSM/T. Data are processed and input into the upper air data base to be used by a variety of analysis programs. SSM/T sounders are a significant input to the high-resolution analysis system (HIRAS), which is a global analysis for the troposphere and stratosphere based on statistical technique known as optimum (or statistical) interpolation. These soundings will also be used as input to the improved point analysis model (IPAM), a model that provides a vertical profile of the state of the atmosphere above any geographic point (chapter V, section A).

c. SSM/I. The SSM/I will provide environmental parameters such as ocean surface wind speed, ice coverage and age, as well as ice edge location, cloud water, liquid water, precipitation, soil moisture, land surface temperature, and a measure of snow depth. These data may be used in a variety of analysis models and applications programs. For example, soil moisture and precipitation rate information may be input to the agricultural meteorology program (AGROMET) and IPAM; land surface temperature and cloud and liquid water may be input to RTNEPH; ocean surface wind speed may be input to HIRAS (if wind direction is available from other sources); and snow depth may be input to the snow depth model. FNOC will also input SSM/I data into its oceanography/meteorology models (chapter IV, section B).

d. SSM/T-2. This sensor will provide moisture soundings. These soundings will be input into the upper air data base to be used by the same analysis programs that currently use SSM/T soundings, i.e., HIRAS and IPAM (chapter V, section A).

2. POES

The NMC, the British Meteorological Service in Bracknell, England, and the European Centre for Medium-Range Weather Forecasts in Reading, England, concentrate their efforts on the Northern Hemisphere weather, though all perform a lesser degree of analysis for the Southern Hemisphere weather patterns. The centers all prepare global forecasts with emphasis placed in the hemispheric region of their principal mission. However, all, and especially NMC, feel that the most significant area meteorologically is the Northeastern Pacific region encompassed by 60 to 30° N. latitude and 120° W. to 170° E. longitudes. This region is extremely volatile, as air masses with extreme differences collide, resulting in rapidly changing weather patterns, with a magnitude significant enough to have a lasting impact on the global hemispheric patterns. A similar set of conditions exists in the North Atlantic (and the violent weather there attests to that), though the magnitude of the continental air masses and the vastness of the ocean fetches does not match that of the Northern Pacific area.

The NMC forecast periods are based on initial conditions as of 0000 Z and 1200 Z. Also important is the age of the data. The Limited-area Fine Mesh (LFM) and spectral global models place emphasis on data that are observed within a time window of 3 hours either side of the 0000 Z and 1200 Z forecast periods. Data either earlier or later (i.e., either more than 3 hours before, or after the observation cutoff times of 0000 Z and 1200 Z) are given less weight in the initial analyses. For this reason, it is important that the NOAA polar-orbiting satellites are positioned to overfly the most meteorologically significant regions of the globe during the window times in order for the satellite data observations to have the greatest impact on the forecast. In the case of the NMC support, the optimum orbit to fly is one flying over the center of the

Northeastern Pacific area circumscribed by 30° to 60° of latitude and 120° W. to 170° E. longitude right at the 0000 Z and 1200 Z observation times. An afternoon ascending orbit crossing the Equator between 1:30 p.m. and 2:15 p.m. local sun time suits that coverage requirement.

Then why the morning orbit? The global analysis products are generated for 6 hour intervals centered about the principal synoptic observing times of 0000 Z, 0600 Z, 1200 Z, and 1800 Z. The descending morning orbit, crossing the Equator southbound at 7:30 a.m., provides coverage over the same important Northeastern Pacific region during the 0600 Z and 1800 Z observation periods. As a result, the morning and afternoon orbits complement each other, providing a global view every 6 hours. Both are over the particularly important Northeastern Pacific during the synoptic data-gathering times of 0000 Z, 0600 Z, 1200 Z, and 1800 Z. Newer forecast models assimilate data on a broader scale more frequently. The dual polar program essentially doubles the data available, and provides the continuity so essential for accurate global forecasting. (The European Centre for Medium-Range Weather Forecasts states that the loss of satellite soundings would force them to revert to climatology, reducing the accuracy of their forecast to a level where the skill at 10 days with satellite data would degrade to a level of only 2 days using climatology.)

As forecast models improve and become more interactive with the data collection process, and as more sophisticated user technologies make greater demands for higher quality and more timely data, timeliness will become an even more critical factor. As a result, a new and expanded data processing system is being installed. This system will reduce the processing and handling time, expand the delivery capabilities, and expand the size of the data base to accommodate improved access to the non-real-time users. These improvements will place even more stringent demands on the timeliness of satellite data, which, in turn, will open a whole new set of observation and delivery requirements that must be met. This synergism never ends, as new capabilities shape new sophistication and technologies that demand faster and more rigid thresholds for the data.

VIII. INTERNATIONAL ASPECTS OF POES

One of the most important elements of the POES system over the past 25 years has been the presence of extensive international participation. Worldwide direct readout not only has provided data necessary for global meteorological monitoring, but also has encouraged countries to integrate satellite observations into their regular weather forecasting activities. Chapter IX describes this aspect in more detail. As countries have become more reliant on satellite data, the need for continuity and technology development has become apparent and countries increasingly are willing to contribute instruments or ground segment services that make the POES system more valuable to them and other users. In this chapter, current and potential hardware and service contributions from other countries are reviewed.

A. LANNION CDA SUPPORT FOR NOAA POLAR SATELLITES

The National Environmental Satellite Data and Information Service (NESDIS) operates and maintains polar-orbiting satellite ground facilities at Gilmore, Alaska; Wallops, Virginia; Lannion, France; and Suitland, Maryland. These facilities are used primarily for command, control, and data capture from the polar satellites. Figure VIII-1 depicts the data capture portion of the polar satellite system. It also shows the command and control communications links to Lannion, France. The Lannion facility has been used as a partial manual-backup command facility. Plans are to install a mini-Command and Data Acquisition (CDA) ground system at Lannion, interconnected with the Satellite Operations Control Center (SOCC), to improve the commanding functions.

1. Lannion Data Flow

There are at least two orbits daily per spacecraft for which the Gilmore and Wallops station coverages do not allow data acquisition from the polar satellites. The Lannion facilities allow the capture of data from these orbits. Stored low-rate data (STIP) from these orbits are downlinked to Lannion and relayed to Suitland (via GOES-East spacecraft, through Wallops, to SOCC) for DPSS processing to meet the NMC cutoff times.

2. Future

NESDIS is planning to improve the current commanding system between the SOCC and Lannion by developing a mini-CDA device interconnecting the SOCC with a 9,600 bps full-duplex link for command and control. This would permit the SOCC to operate through Lannion as it does through Gilmore or Wallops. Command throughput is expected to improve from the present

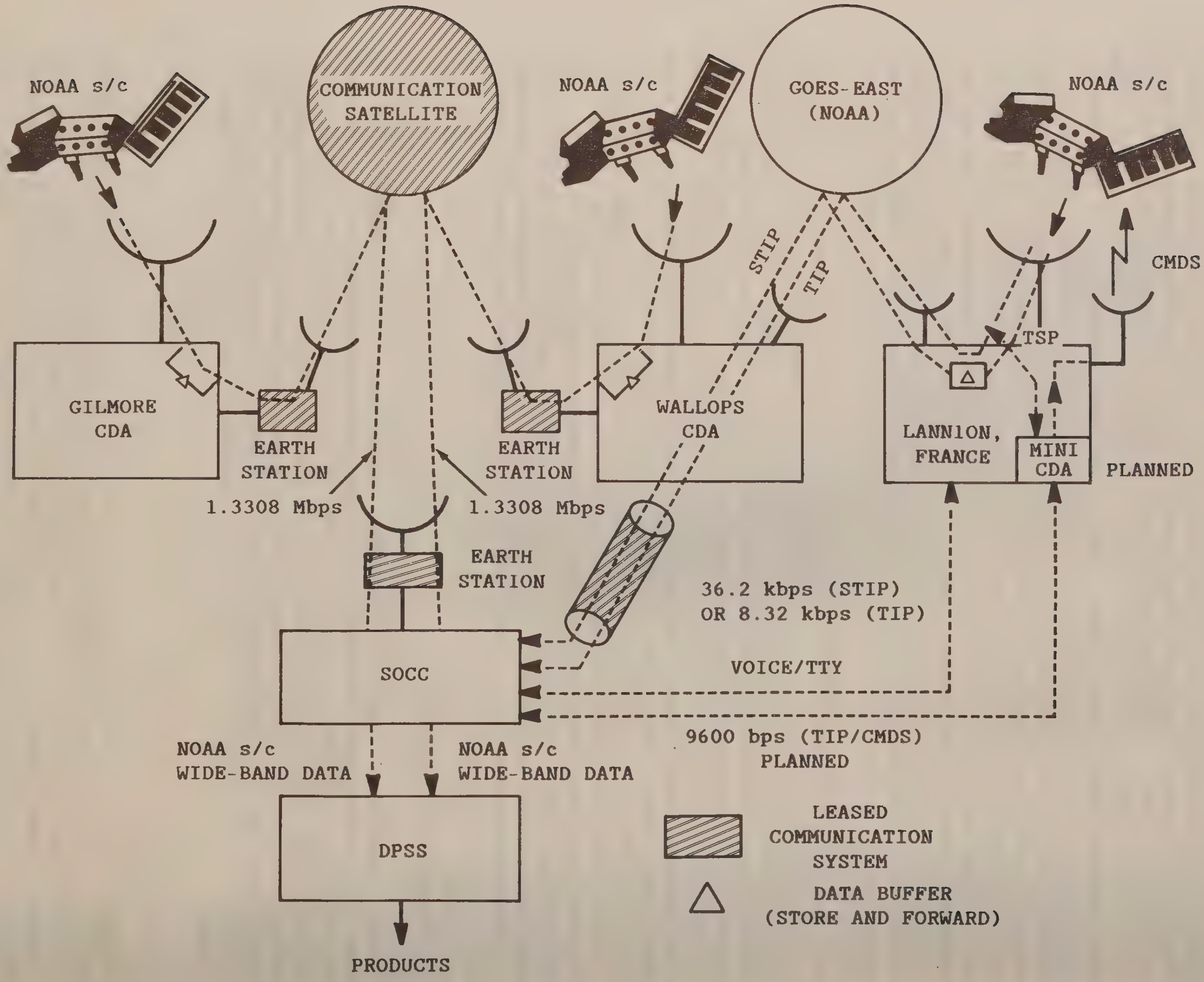

NOAA s/c
COMMUNICATION SATELLITE
NOAA s/c
GOES-EAST (NOAA)
NOAA s/c
STIP
TIP
CMDS
TSP
GILMORE CDA
EARTH STATION
WALLOPS CDA
EARTH STATION
LANNION, FRANCE
MINI CDA
PLANNED
1.3308 Mbps
1.3308 Mbps
EARTH STATION
36.2 kbps (STIP)
OR 8.32 kbps (TIP)
SOCC
VOICE/TTY
9600 bps (TIP/CMDS)
PLANNED
NOAA s/c
WIDE-BAND DATA
NOAA s/c
WIDE-BAND DATA
DPSS
PRODUCTS
LEASED COMMUNICATION SYSTEM
DATA BUFFER (STORE AND FORWARD)

Figure VIII-1
NOAA Polar-Orbiting Satellite Wide-Band
Data Communications Links

7 commands per pass, to 70 to 140 commands per pass. This will make for a more reliable command system for use in launch support and to correct spacecraft anomalies. Optional units may be added to other sites. Figures VIII-2 and VIII-3 provide a more detailed data diagram for the Western European System (WES), composed of Lannion, Wallops, and SOCC facilities.

B. STRATOSPHERIC SOUNDING UNIT/ADVANCED MICROWAVE SOUNDING UNIT

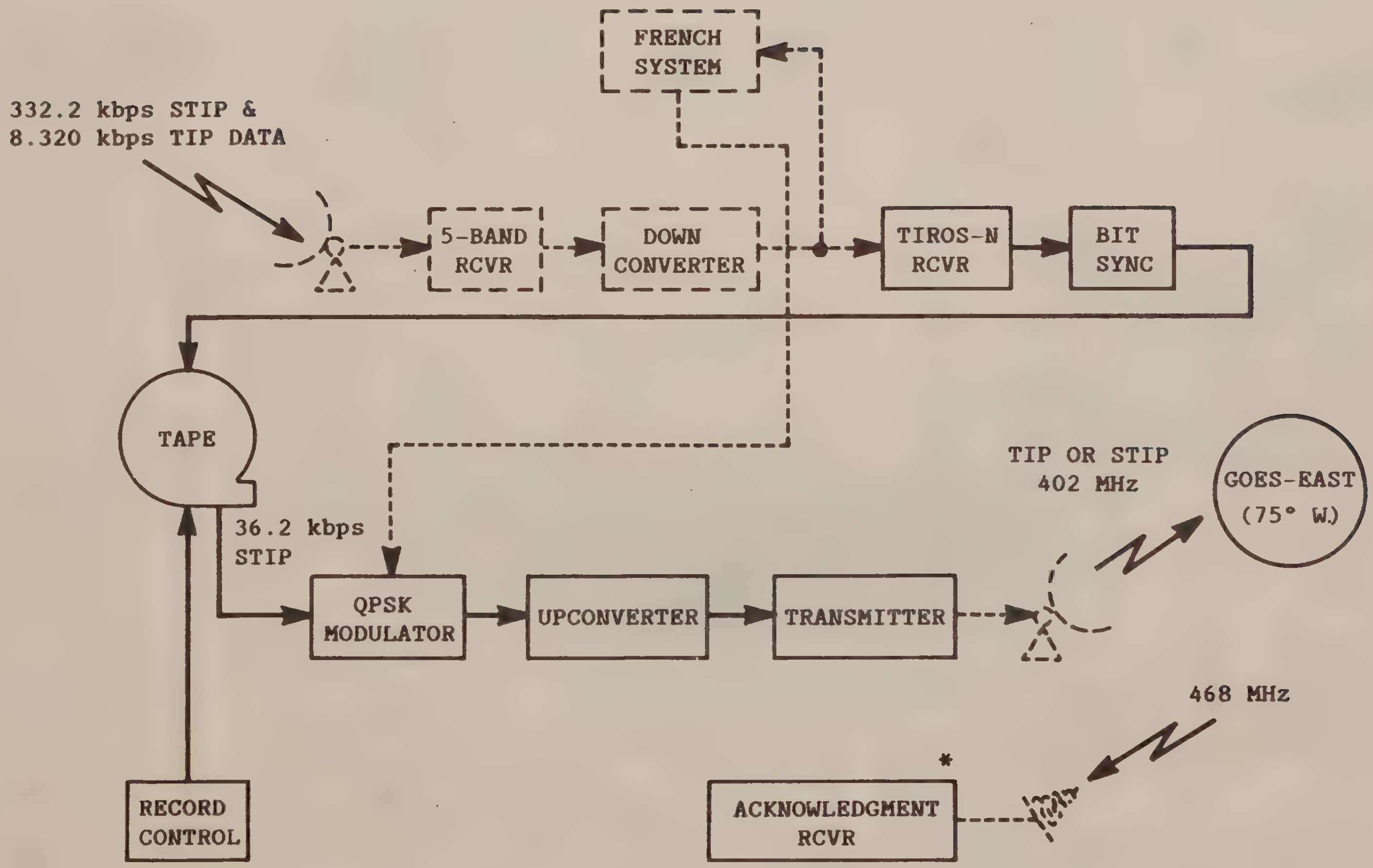
Under an MOU signed in September 1974, the United Kingdom's Meteorological Office provides the SSUs that NOAA flies on its polar-orbiting satellites as part of the TOVS. In exchange, NOAA transmits raw and processed TOVS data to the U.K. The SSU is a three-channel instrument with 147 km resolution that measures temperatures in the stratosphere. The SSU data are combined with the other elements of TOVS to produce vertical temperature profiles that are used for global numerical modeling of the atmosphere.

The AMSU is scheduled to replace the SSU and the MSU beginning with NOAA K. The AMSU is a 20-channel radiometer designed to provide data that will be used to derive temperature soundings, water vapor profiles, and information on precipitation and ice. The instrument has two separate portions: a temperature sounding unit, AMSU-A, and a water vapor profiling module, AMSU-B. The AMSU-B module will be furnished by the United Kingdom; the AMSU-A will be provided by NOAA. The AMSU-B is a five-channel radiometer containing channels at 89 GHz, 166 GHz, and three channels at 183 GHz. Its IFOV will be 15 km, almost 10 times better than the present SSU and MSU.

Data from the SSU, along with other TOVS channnels, are transmitted via land line to the Meteorological Office as the data from each orbit are received in Suitland. NOAA K will have a similar type of data transfer, with the data from the AMSU-B and AMSU-A stripped out early in the processing flow and transmitted to the United Kingdom. Satellite data transfer via commercial satellites may replace the present land line link after NOAA K. Access to all data produced by the TOVS is available to the U.K. Meteorological Office.

C. ARGOS DATA COLLECTION AND PLATFORM LOCATION SYSTEM

The Argos system was designed to provide an operational environmental satellite data collection, location, and dissemination service for the NOAA POES program. It was established under a 1974 MOU between NASA and NOAA for the United States, and the CNES for France. (This MOU is being renewed during 1985). The system became fully operational in 1979 with the launch of TIROS-N. Currently, the Argos system monitors


332.2 kbps STIP &
8.320 kbps TIP DATA
5-BAND RCVR
DOWN CONVERTER
FRENCH SYSTEM
TIROS-N RCVR
BIT SYNC
TAPE
36.2 kbps STIP
QPSK MODULATOR
UPCONVERTER
TRANSMITTER
TIP OR STIP 402 MHz
GOES-EAST (75° W.)
468 MHz
*
ACKNOWLEDGMENT RCVR
RECORD CONTROL

* CURRENTLY NOT BEING USED

Figure VIII-2
Lannion Segment of Western European System (WES)

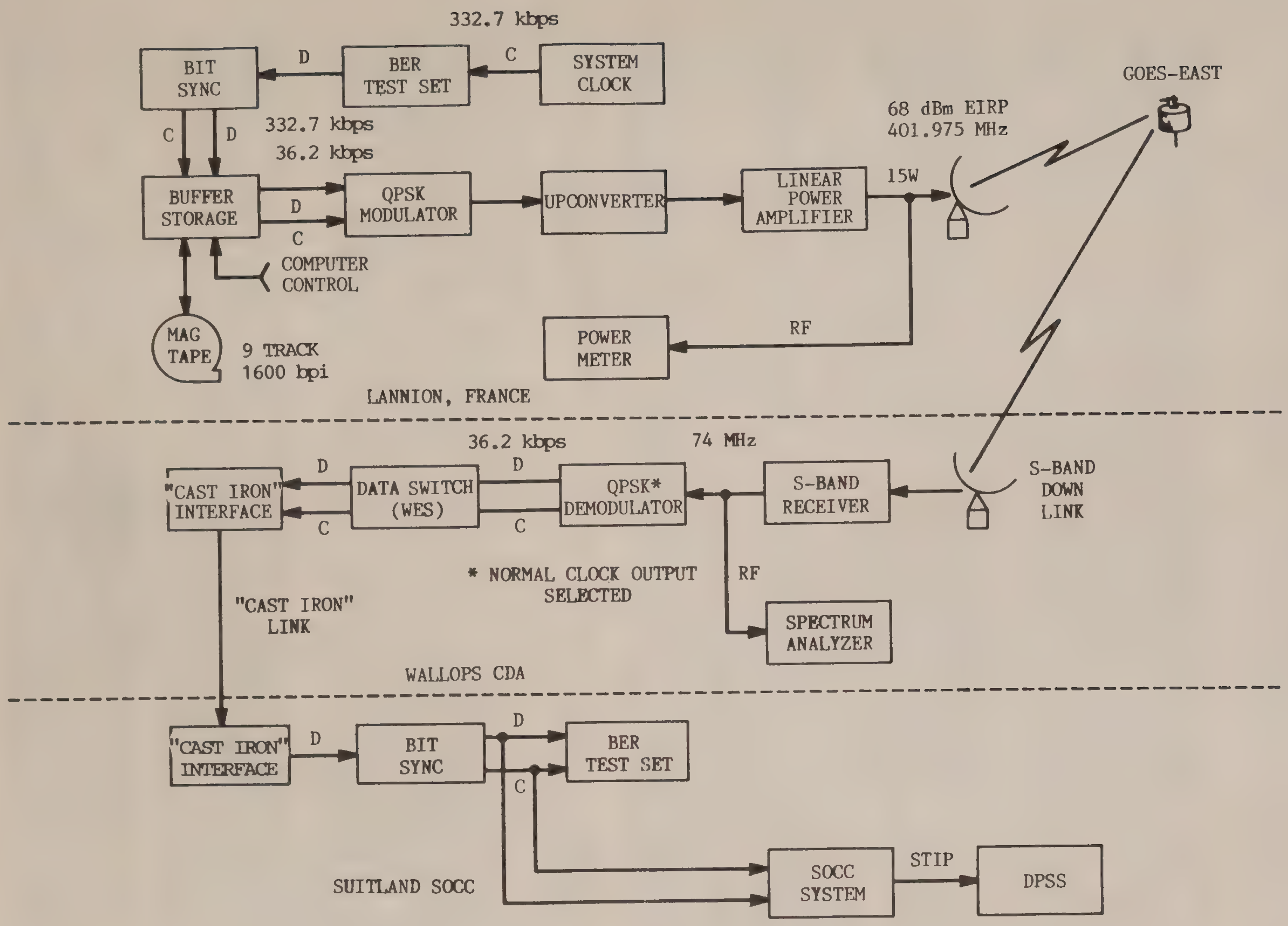

332.7 kbps
BIT SYNC
D
BER TEST SET
C
SYSTEM CLOCK
GOES-EAST
C
D
332.7 kbps
36.2 kbps
68 dBm EIRP
401.975 MHz
BUFFER STORAGE
D
C
QPSK MODULATOR
UPCONVERTER
LINEAR POWER AMPLIFIER
15W
COMPUTER CONTROL
MAG TAPE
9 TRACK
1600 bpi
POWER METER
RF
LANNION, FRANCE
36.2 kbps
74 MHz
D
D
"CAST IRON" INTERFACE
DATA SWITCH (WES)
QPSK* DEMODULATOR
S-BAND RECEIVER
S-BAND DOWN LINK
C
C
* NORMAL CLOCK OUTPUT SELECTED
RF
"CAST IRON" LINK
SPECTRUM ANALYZER
WALLOPS CDA
"CAST IRON" INTERFACE
D
BIT SYNC
D
BER TEST SET
C
SUITLAND SOCC
SOCC SYSTEM
STIP
DPSS

Figure VIII-3
Lannion/Wallops/SOCC Polar System

approximately 240 fixed and 500 moving platforms from 17 countries, each equipped with sensors and a Platform Transmitter Terminal (PTT).

The Argos space instrumentation is flown aboard POES satellites. The onboard DCS receives messages transmitted by PTTs, processing them for PTT identification, the time of reception, and the measurement of the Doppler shift in the received signal. Since there are normally two satellites in operation, a minimum of six positions per day are obtained from a PTT near the Equator, and up to 28 positions per day in polar areas.

Argos data are received at the three telemetry receiving stations (Wallops, Gilmore, and Lannion) and relayed to the NOAA/NESDIS facility in Suitland. At Suitland, the Argos data are separated and forwarded via a commercial carrier to the Argos Data Processing Center in Toulouse, France. The following processing operations are performed at Toulouse:

- Decoding of the received PTT messages and conversion of data into physical units

- Accurate computation of the satellite orbit

- Computation of PTT positions from orbital data combined with Doppler shift data computed by the Argos instrument

- Storage of all these results on computer-accessible files for user access

Users requiring data in real time receive data directly from the satellite on the S-band or VHF beacon. Since each transmission is rebroadcast by the satellite as soon as it is received, anyone with a suitable receiver within range of the satellite can receive the data. Several of these receivers, which are called LUTs, are operated by users, including Service Argos in Toulouse. Services provided by the system include:

- The relay of in situ observations of surface and upper level ocean conditions and surface weather conditions. The location of moving platforms provides information on surface currents (buoys), or on middle or upper level winds (balloons).

- The capability to track the movement of oceanic research ships and marine animals in research programs.

- The relay of in situ environmental data from those platforms in the Arctic and Antarctic that are not observable from the data collection systems on the NOAA geostationary satellites. These data provide vital inputs to analyses of weather patterns transiting the polar regions.

- Argos-equipped buoys are placed in regions where ocean currents are expected to carry icebergs into shipping lanes. Also, buoys are attached to drifting icebergs to verify berg-drift forecasts based on ocean current rates.

There are several ways in which the data collected by the Argos system may be obtained. They are available from computer files accessible by telephone, telex, or communication networks, generally within 4 hours after the receipt of data from the satellite. Processed data can be made available on computer-compatible tapes (CCTs) or printouts, either every 2 weeks or monthly. Appropriately formatted data are also distributed over the World Meteorological Organization's (WMO) GTS.

NOAA is considering an increase in power and platform area for NOAA K, L, and M. This increase is principally intended to support the AMSU. Nevertheless, sufficient reserve power and space remain for Argos to double its current system capacity. Service Argos has projected system usage growth to expand to about 10,000 platforms by 1995. For this reason, Service Argos hopes to join NASA and NOAA in utilizing new developments such as the polar platform, a component of the U.S. Space Station project.

D. COSPAS/SARSAT

1. Present System

Since the mid-1970's, a number of countries have been interested in the concept of using satellites equipped with suitable receivers to detect and locate emergency transmissions from aircraft and ships in distress. This mutual interest led to the formation of the COSPAS/SARSAT project, an international joint venture in satellite-aided search and rescue. The partners in this joint venture are Canada's Department of Communications (DOC), France's CNES, the United States' NASA, and the U.S.S.R's Ministry of Merchant Marine (MORFLOT). The objective of the COSPAS/SARSAT project is to demonstrate that detection and location of distress signals can be greatly facilitated by the use of a global monitoring system based on low-altitude, near-polar-orbiting spacecraft.

The global coverage of polar-orbiting satellites, coupled with this universal need to improve search and rescue services, has led to increased international interest and participation in the endeavor. The United States, Canada, and France have jointly developed the SARSAT system, which is flying on the

NOAA satellites. The COSPAS system was developed by the Soviet Union.

One of the characteristics of a satellite in a low polar orbit is that it will "see" the entire globe once every 12 hours, but the contact time with any one area is relatively short. Thus, the waiting time between the activation of a distress transmitter and its detection by a satellite is significantly reduced by having more than one satellite available. In a constellation of four satellites, the mean waiting time is approximately 1 hour at mid-latitudes. At higher latitudes, where the weather is more hostile, waiting time is less than 30 minutes, making survival chances higher where time is most critical. Thus, through cooperation between COSPAS and SARSAT, more satellites could be funded and launched than could be done separately, permitting an enhanced capability.

Simply stated, the concept involves the use of multiple satellites "listening" for distress transmissions. The signals received by the satellites are relayed to a network of dedicated ground stations, where the location of the emergency is determined by measuring the Doppler shift between the satellite, with a precisely known orbit, and the distress signal. The information is then relayed to a Mission Control Center (MCC), which alerts the appropriate Rescue Coordination Center (RCC). The RCC then begins the actual search and rescue operation in accordance with the conventional practice.

The joint COSPAS/SARSAT Project was formalized by an MOU signed in November 1979. Interoperability between the two systems was thus established, allowing all participating nations to use both systems to detect and locate emergencies.

Two experiments were conducted initially. The first was designed to serve aircraft and vessels equipped with commercially available emergency transmitters, operating at 121.5 and 243 MHz. The second, currently in progress, uses transmitters operating at 406 MHz that are designed specifically for satellite detection.

The first satellite within the framework of the joint COSPAS/SARSAT project was launched by the Soviet Union on June 30, 1982. During March 1983, the second COSPAS satellite and the first SARSAT-equipped satellite, NOAA E (NOAA 8), were successfully launched. In June 1984, NOAA 8 suffered a catastrophic failure, rendering it inoperable for SARSAT needs from that date until June 1985, when it was recovered. At the same time, the Soviet Union launched its third COSPAS spacecraft to support the project, as the longevity of COSPAS I was becoming questionable. The second NOAA spacecraft, NOAA F (NOAA 9), was launched in December 1984 and to date is functioning normally.

Norway, Sweden, the United Kingdom, Finland, and Bulgaria are also participating in the joint project to evaluate its effectiveness in their search and rescue regions. At least a dozen other nations are actively considering participation at this time.

2. Future Systems

The new understandings that have been signed represent an agreement by the COSPAS/SARSAT partners to continue the systems, including a commitment to continued COSPAS satellites and Canadian and French SARSAT instruments on NOAA satellites for at least the next 7 years. The agreements provide flexibility to extend these commitments from year to year, indefinitely. They also offer flexibility to undertake technical or administrative modifications to improve system utility, subject to agreement among the parties and funding availability.

E. DMSP

DMSP data are shared with allied military forces as needed to meet requirements for combined operations and disaster/rescue efforts. Data are provided to NOAA/NESDIS for nondiscriminatory distribution to the international community.

IX. DOMESTIC AND INTERNATIONAL BROADCAST SERVICES

A. APT, HRPT, AND DSB SERVICES OF POES

This chapter discusses the broadcast services of DMSP and POES. POES broadcasts are accessible to any receiving station and include sensor, system, and SARSAT data. DMSP broadcasts are provided for receiving stations that have been authorized and equipped for the use of these transmissions.

Few technological developments have had as much impact on the world's population as environmental satellite direct data broadcast services. Since 1963, government, military, and private organizations in more than 120 countries have invested hundreds of millions of dollars in direct broadcast ground receiving equipment and huge amounts for personnel and facilities to support direct broadcast data utilization for national and private purposes. These undertakings have spread the benefits of environmental satellites to almost every point on the globe.

The methods by which direct broadcast services--Automated Picture Transmission (APT), High Resolution Picture Transmission (HRPT), and Direct Sounder Broadcasts (DSB)--are made available are described in the section on Data Availability in chapter IV. Chapter IX is concerned with the domestic and international roles of direct broadcast services.

1. Domestic Role

a. APT. The idea of transmitting satellite imagery directly to weather forecast offices was not incorporated into the original operational plans for TIROS-I. However, when meteorologists in Washington, D.C., began looking at TIROS-I cloud pictures, and comparing them with conventional observations and analyses, it was decided that nephanalysis, or cloud depiction charts, would be prepared from the images and transmitted to other weather forecast offices around the country via conventional land-line weather facsimile circuits.

These early satellite "nephs," with new and strange symbols, were not well accepted by field meteorologists, who found it awkward to relate them to conventional data; also, they often arrived too late to be useful operationally. In consequence of this and within months of the launch of TIROS-I, plans were made to develop a system for sending imagery directly to forecast offices. RCA and NASA, working together, designed and developed a TV vidicon system--the first APT--and ground receiving equipment to receive "live" pictures. The system was first flown on TIROS-VII in 1963.

Soon, APT ground receiving equipment was installed in 13 U.S. Weather Bureau forecast offices within the continental United States, and at U.S. Navy and Air Force installations overseas. Meteorologists in other countries saw these pictures, realized their importance, and began acquiring stations of their own to receive them. With the advent of the scanning radiometer, nighttime image acquisition became possible. This capability was extended and enhanced with the introduction, in 1972, of the Very High Resolution Radiometer.

Until the late 1970's, APT services were not used broadly in domestic programs, the exception being the military services of the United States, which utilize these services as backup to the DMSP. For most Federal and private users of satellite products within the United States, the introduction of land-line dissemination of data from geostationary environmental satellites, which began in 1976, satisfied most needs for satellite imagery or digital products.

In recent years, however, more government agencies have begun to utilize APT services. APT systems are relatively inexpensive and easily transportable, and can be used by field parties or aboard vessels to obtain weather information in the absence of, or to complement, conventional weather observations or forecasts. NOAA finds that the use of APT systems assists success in field experiments at remote locations. NOAA's research vessel, the Oceanographer, carried an APT system on one of its around-the-world cruises, and the Glomar Challenger used APT to support deep-sea drilling projects around the world. The R/V Knorr, and numerous other research vessels, have used APT equipment to study ocean currents and temperature structure in the Gulf of Mexico and along the United States east and west coasts, and to observe and map sea ice along the Alaska coast and in the Canadian Archipelago and the Antarctic.

Oceanographic officers on aircraft carriers and icebreakers frequently reported instances when storms not depicted on conventional weather charts were detected in APT images and were avoided. Other government agencies, such as the Bureau of Reclamation, working with overseas governments in activities such as weather modification, agrometeorology, crop monitoring, search and rescue, or disaster warning services, find it necessary to work with APT products. Numerous government agencies overseas are asking U.S. Government guidance in upgrading their meteorological services. In nearly every case, direct readout of APT data is considered an essential part of the upgrading of their facilities.

b. HRPT. The HRPT system, flown for the first time in 1972, was designed to permit NOAA's San Francisco, California, weather office to obtain real-time satellite observations of the eastern Pacific for forecasting purposes. Today there are more than 100 HRPT stations in operation. Of this number, about 30 are operated by U.S. agencies, primarily the DOD. Most of the 30 are located outside the continental United States, or are self-contained, deployable units. The remaining 70-odd stations are foreign owned and operated.

Aside from NOAA's HRPT receiving systems in Virginia, Alaska, and California, and a NASA research and development system in Maryland, other domestic operators of HRPT systems include the Scripps Institute of Oceanography and two Navy facilities, one at the Navy Environmental Research and Prediction Facility in Monterey, California, and the other at the Naval Ocean Research and Development Activity in Bay St. Louis, Mississippi. Direct reception of HRPT data at these latter three is largely directed toward oceanographic research and operational activities.

As the benefits that can be derived from direct readout HRPT data are becoming better known, more domestic agencies are planning to establish HRPT receiving and processing capabilities. A major program to utilize HRPT in the New England area is being developed by the Northeast Area Remote Sensing System (NEARSS), a consortium of government and academic organizations with primary interests in oceanographic applications, including fisheries and ocean current and temperature studies. The Department of the Interior is investigating the use of HRPT data for forest fire fuel assessment and fire containment, and USDA is examining vegetation indexing using high-resolution environmental satellite imagery.

c. DSB. While 16 countries, including the United States, currently receive and process atmospheric soundings generated by TOVS on the polar-orbiting NOAA satellites, the domestic use of DSB services is limited largely to extensive research efforts to standardize the processing of DSB data. This activity, being conducted at the University of Wisconsin's Cooperative Institute for Meteorological Satellite Studies, is directed toward helping other nations develop the capability to receive, process, and utilize satellite soundings in national or regional numerical forecast programs. Any organization with the proper receiving equipment can acquire atmospheric sounder data via direct readout from the satellite, but the reduction of these data to useful atmospheric profiles is a complex process. From 1972 until 1982, no more than five countries had developed the capability to accomplish such data processing.

The 14 countries with this capability today, and the eight countries currently planning to receive and process DSB data, owe a great deal of their success to the research efforts being carried out at the University of Wisconsin and by other research groups.

2. International Role

International use of APT, HRPT, and DSB direct broadcast services far outweighs domestic use, primarily because U.S. users have access to high-quality geostationary satellite products distributed over land lines. The direct readout stations operated by the environmental service agencies of other nations often are located with the communications centers of those agencies, to speed the dissemination of satellite information. Some countries, Australia and Brazil for example, operate multiple direct readout stations to overcome the inconveniences of developing national single-circuit land-line distribution systems to cover huge geographic areas with difficult terrain and scattered population centers. Nations and regions with vast areas that are not covered by weather reporting stations depend on direct readout data for observations covering those areas. Maritime nations, especially island countries, need the data that direct broadcast services can best supply.

a. APT. As stated earlier, at least 1,000 APT stations are in operation. More than 350 of these are operated by government agencies.

b. HRPT. Almost without exception, the 14 countries with HRPT reception capabilities today began their operations with the lower resolution APT data. The number of countries using HRPT data is increasing. Countries that receive HRPT are archiving the data for other customers. In Italy, for example, the HRPT imagery used by the Food and Agriculture Organization for locust control efforts in northern Africa comes from the archives of the French station in Lannion.

Most HRPT stations have been bought from commercial organizations by government agencies, for a cost ranging between $0.5 and $1.0 million. These stations support a wide variety of research and operational activities requiring higher resolution data than that available through APT services. In Australia, Thailand, and elsewhere, hydrologic events are high on the list of phenomena being investigated.

c. DSB. Afternoon thunderstorm activity, the height at which clouds will begin to form, forecasting rain/sleet/snow in the wintertime--these and many other types of forecasting activities have, for nearly five decades, depended entirely upon the ability to collect data in the upper atmosphere through the use of balloon-borne radiosonde instruments from stations highly concentrated in the Northern Hemisphere, and largely land based. The development of the Vertical Temperature Profile Radiometer (VTPR) and its successor, the TOVS, changed the methods of obtaining such observations on a global scale. The DSB service enables any user with the proper equipment to receive satellite signals that can be converted into atmospheric soundings, greatly supplementing the information available for making these forecasts.

3. Conclusions

The three polar-orbiting satellite direct broadcast services discussed here, the APT, HRPT, and the DSB services, are fine examples of the global utility that can be realized from the POES program. Any person or any country, anywhere in the world, can access data directly from these environmental satellites, without any financial, legal, or political preconditions or obligations.

B. SARSAT H, I, J AND BEYOND

In view of the successful demonstration of the system, the COSPAS/SARSAT nations have agreed to continue to operate and to provide search and rescue satellite services until at least 1990. The COSPAS/SARSAT system will consist of four satellites, two provided by the U.S.S.R. and two provided by the SARSAT countries. The decision to extend the COSPAS/SARSAT service was made to permit the continuity of service, while the planning for the establishment of a future global operational satellite-aided search and rescue system is concluded.

The SARSAT countries will continue to provide service at 121.5 MHz, 243 MHz, and 406 MHz on the NOAA series of weather satellites. The U.S.S.R. will provide service at 121.5 MHz and 406 MHz on the COSPAS series of satellites. In general, the system provided to 1990 will build upon the experience attained during the COSPAS/SARSAT demonstration and evaluation phase.

At 121.5 MHz, improvements will be made to the LUTs to enhance system performance. The regional coverage provided by COSPAS/SARSAT will increase through the deployment of additional LUTs. At 406 MHz, and beginning with NOAA H, the SARSAT satellite will provide a global dump mode similar to that now provided by the COSPAS satellites. A solid-state memory will be provided to hold SAR data until the satellite can transmit them to a LUT. Beacon development at 406 MHz will continue to ensure that reasonable cost beacons, which meet all necessary performance specifications, will be available in the future. Finally, the optimum use of COSPAS/SARSAT data with geosynchronous satellite data is being investigated. One experiment is to determine if SAR performance can be enhanced by adding geosynchronous satellite alerting data to complement position-locating data provided by low-altitude polar-orbiting satellites.

In order to reduce the volume of nondistress data passed between the various COSPAS/SARSAT MCCs, LUTs are being upgraded to generate their own ephemeris data, excluding the need to exchange calibration beacon data. Finally, efforts are under way in some countries to expand the potential user community to include such users as scientific and sports expeditions.

C. DMSP DIRECT BROADCASTS TO TACTICAL TERMINALS

The role of the DMSP Tactical Terminal is to provide direct readout of real-time visible and infrared imagery, primarily from DMSP satellites, and secondarily from NOAA polar-orbiter satellites. Seventeen USAF terminals are employed to support (and are colocated with) key command and control organizations. Of these terminals, two USAF terminals are available for deployment in support of short-notice global contingencies. Units supported include USAFE, CENTCOM, REDCOM, USSOUTHCOM, AAC, PACAF, Joint Typhoon Warning Center, and the Western Test Range. Current models include the Mark IIA, III, and IV. Future upgrades will include incorporation of SSM/I, SSM/T, and SSM/T-2 data processing capability and geostationary satellite imagery capability.

Eight Navy conventional and nuclear-powered attack aircraft carriers (CV/CVN) have a DMSP direct readout capability (SMQ-10). In addition, two Navy tactical terminals (TMQ-29) are located in San Diego, California, and Rota, Spain. Beginning in 1988, the Navy is planning to deploy 65 follow-on SMQ-11 satellite receivers. This upgraded receiver will allow afloat and ashore oceanographers to copy data from the DMSP, NOAA POES, GOES, and the new N-ROSS satellites. Forty-two SMQ-11 units will be deployed aboard major combatant and command and control ships, and 23 will be located around the world at major Navy shore installations.

The Marine Corps has procured seven of 12 planned Mark IV tactical terminals for assignment to Marine Air Base Squadrons to support air operations. These Mark IVs are prepared to deploy worldwide with their supported air units.

X. SHARED PROCESSING

Shared processing is the exchange of polar-orbiting meteorological satellite data among NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), the U.S. Navy's Naval Oceanography Command (NOC), and the U.S. Air Force's Air Weather Service (AWS). The goal of shared processing is to exchange data bases freely among the agencies' operational centers, and to integrate those data bases into each center's ground data processing operations. Access to each agency's data bases will minimize processing duplication, maintain a high degree of backup capability between centers, provide civilian near-real-time access to sensor data not on, or planned for, NOAA spacecraft, and improve the overall quality of existing products through the addition of new sensor data.

An MOA was signed in 1984 that established the means to implement shared processing through a center of expertise concept in which each agency would produce and distribute certain data and products for the other two agencies. The agency operational centers are located at NESDIS, Suitland, Maryland; AFGWC, Offutt AFB, Omaha, Nebraska; and FNOC, Monterey, California. Each of these centers will be interconnected by high-speed domestic satellite (Domsat) communications.

A. SYSTEM DESCRIPTION

The shared processing system consists of two primary components, communications processing and ground processing. These components are depicted in figure X-1 for each of the operational centers. The communications component consists of leased wideband and narrowband services. Narrowband communications will be leased phone lines interconnecting each center for operational voice control. The wideband communications will consist of a 1.3308 Mbps (million bits per second) channel leased from a Domsat carrier. Each center currently has an unmanned Earth station (11 meter antenna) to receive and transmit its data. The Domsat service will be leased from RCA American Communications.

Ground processing for shared processing will be performed at each center's operational processing facilities, all of which are undergoing major upgrades to accommodate their agency's expanding missions. These facilities are the data processing and services system (DPSS) at NESDIS, the satellite data handling system (SDHS) at AFGWC, and the satellite processing center (SPC) at FNOC. Each agency is responsible for implementing the various functions necessary to support shared processing at each of their centers. Primary functions that will be required at each center are formatting data and products

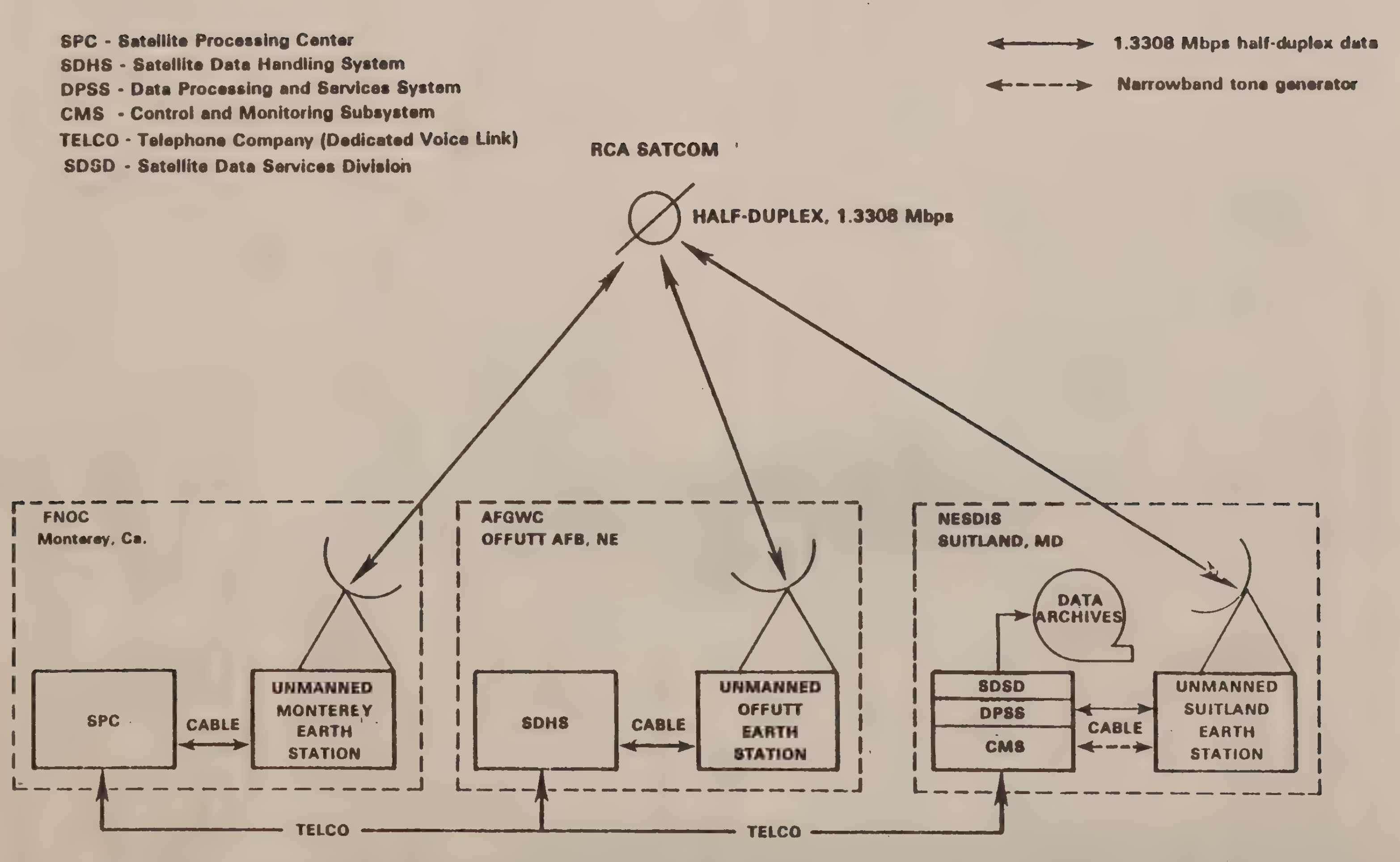

SPC - Satellite Processing Center
SDHS - Satellite Data Handling System
DPSS - Data Processing and Services System
CMS - Control and Monitoring Subsystem
TELCO - Telephone Company (Dedicated Voice Link)
SDSD - Satellite Data Services Division
1.3308 Mbps half-duplex data
Narrowband tone generator
RCA SATCOM
HALF-DUPLEX, 1.3308 Mbps
FNOC
Monterey, Ca.
SPC
CABLE
UNMANNED MONTEREY EARTH STATION
AFGWC
OFFUTT AFB, NE
SDHS
CABLE
UNMANNED OFFUTT EARTH STATION
NESDIS
SUITLAND, MD
DATA ARCHIVES
SDSD
DPSS
CMS
CABLE
UNMANNED SUITLAND EARTH STATION
TELCO
TELCO

Figure X-1
Shared Processing Network Configuration

for transmission, transmitting the data over Domsat, receiving incoming data via Domsat, quality control, and operational control and monitoring. The network manager will be NESDIS, with a control and monitoring subsystem (CMS) installed in the DPSS in Suitland, Maryland. The CMS will provide overall system coordination, and turn on and off each processing center's transmissions (as well as verify receipt of commands) by means of a tone generator and receiver, where the tones are transmitted via satellite transmission. A data archive function will also be located in the DPSS. Data exchanges will be operated on a scheduled basis, starting with four transmissions per 24 hours for each center, and eventually evolving into a near-real-time operation, approximately an orbit-by-orbit schedule.

B. CENTERS OF EXPERTISE

Each center has been designated as a center of expertise (COE) for the product area it has traditionally considered as high priority in meeting its agency's mission. NOAA (NESDIS) is the COE for global atmospheric soundings, AFGWC is the COE for global mapped imagery, and the FNOC is the COE for global oceanographic data products.

Under this concept, each processing center is responsible for the production and distribution (Domsat transmission) of the data and products it has agreed to in the MOA. Each COE will have access to, and will integrate into its ground data processing, raw sensor data from both NOAA and DMSP spacecraft. For example, NESDIS will produce and distribute, for operational use, sounding products produced from the DMSP SSM/T, in addition to producing soundings from the NOAA spacecraft's TOVS. NESDIS also plans to integrate data from the DMSP SSM/I, which will be flown in late 1986, into the operational soundings program to improve the overall quality of the products.

AFGWC, the COE for mapped imagery, currently receives all global Command and Data Acquisition (CDA) readouts from both DMSP and NOAA spacecraft. Primary sensor data processed at AFGWC are from the DMSP OLS and the NOAA AVHRR. AFGWC has the capability to integrate both data sources into its dynamic image data base, called the Satellite Global Data Base (SGDB), and uses the NOAA data primarily for backup operations. Under shared processing, NOAA will routinely receive the higher quality DMSP imagery.

FNOC, the COE for oceanographic products, can also receive global data from DMSP and NOAA spacecraft. Oceanographic products will be generated from NOAA AVHRR and DMSP SSM/I sensors.

Common to all operational centers will be an effort to provide backup assistance to each other in the event of a failure somewhere in the ground or space segments. Backup operations will provide data continuity, and will assure the continuation of product generation and delivery. Backup operations are currently in the planning stages; however, a typical backup scenario could have NESDIS backup FNOC and provide sea-surface measurements, AFGWC backup NESDIS and provide soundings, and FNOC backup AFGWC and provide mapped image products.

C. PRODUCT MIX

Products to be exchanged in shared processing are partitioned according to the COE concept. Described below are the products expected to be exchanged as part of the initial operating capability (IOC).

NESDIS, the COE for atmospheric soundings, will produce and distribute sounding products from both DMSP and NOAA satellites. DMSP soundings will be produced from SSM/T data (with SSM/I data added later), and will consist of the following parameters: layer mean temperatures for 15 layers, atmospheric temperatures for 40 pressure levels, geopotential heights for 17 pressure levels, tropopause temperature, tropopause pressure, brightness temperatures, and surface height. NOAA soundings, derived from the TOVS sensors, will consist of a similar set of parameters, plus layer precipitable water in three layers, water vapor mixing ratios for 15 pressure levels, total ozone measurements, surface albedo, skin temperatures, and cloud amounts for 10 pressure levels.

AFGWC, the COE for mapped imagery, will distribute its satellite global data base (SGDB) and real-time nephanalysis (RTNEPH) data bases. The SGDB is a dynamic data base where the latest available infrared and visual satellite imagery data are stored. Data sources include both DMSP and NOAA satellites. The imagery consists of daytime visible and daytime and nighttime infrared data. The smallest resolution element of the SGDB is 3 by 3 nmi, and represents a single data point. The SGDB is available in three formats: Northern Hemisphere polar stereographic, Southern Hemisphere polar stereographic, and Mercator. The polar formats represent a 4,096 by 4,096 element array; the Mercator is a 4,096 by 2,716 array. All elements are represented by gray-scale values ranging from 1 to 64. The RTNEPH data base integrates conventional observations (pilot reports, surface observations, etc.) with visible and infrared satellite data. The data base contains the amount of cloud at four floating layers (heights) of the atmosphere. In addition to distributing these data bases, AFGWC will transmit raw SSM/T data (and eventually SSM/I) as input to the NESDIS DMSP atmospheric sounding program.

FNOC, the COE for oceanographic products, will produce products from AVHRR and SSM/I sensors. AVHRR data will be used to derive global multichannel sea-surface temperatures. SSM/I products will consist of antenna temperatures called temperature data records (TDRs), brightness temperatures called sensor data records (SDRs), radiative transmissivity data, and environmental data records (EDRs). The TDRs will contain Earth-located, calibrated antenna temperatures prior to antenna pattern correction; the SDRs are similar but with the pattern correction applied to the data. The radiative transmissivity data will be produced for SSM/I "all-channel" scenes that have a resolution of 25 km. The EDRs are Earth-located meteorological and oceanographic measurements corresponding with the surface type (ocean, land, ice) of the observation. The environmental parameters calculated for each surface type will be as shown in table X-1.

Table X-1
Environmental Parameters for Selected Surface Types

Surface Type	Environmental Parameter
Ice	Sea Ice Age Sea Ice Concentration Sea Ice Edge Cloud Water
Land	Rain Rate Soil Moisture Cloud Water Liquid Water Surface Temperature Snow Depth
Ocean	Surface Wind Rain Rate Cloud Water Liquid Water Precipitable Water

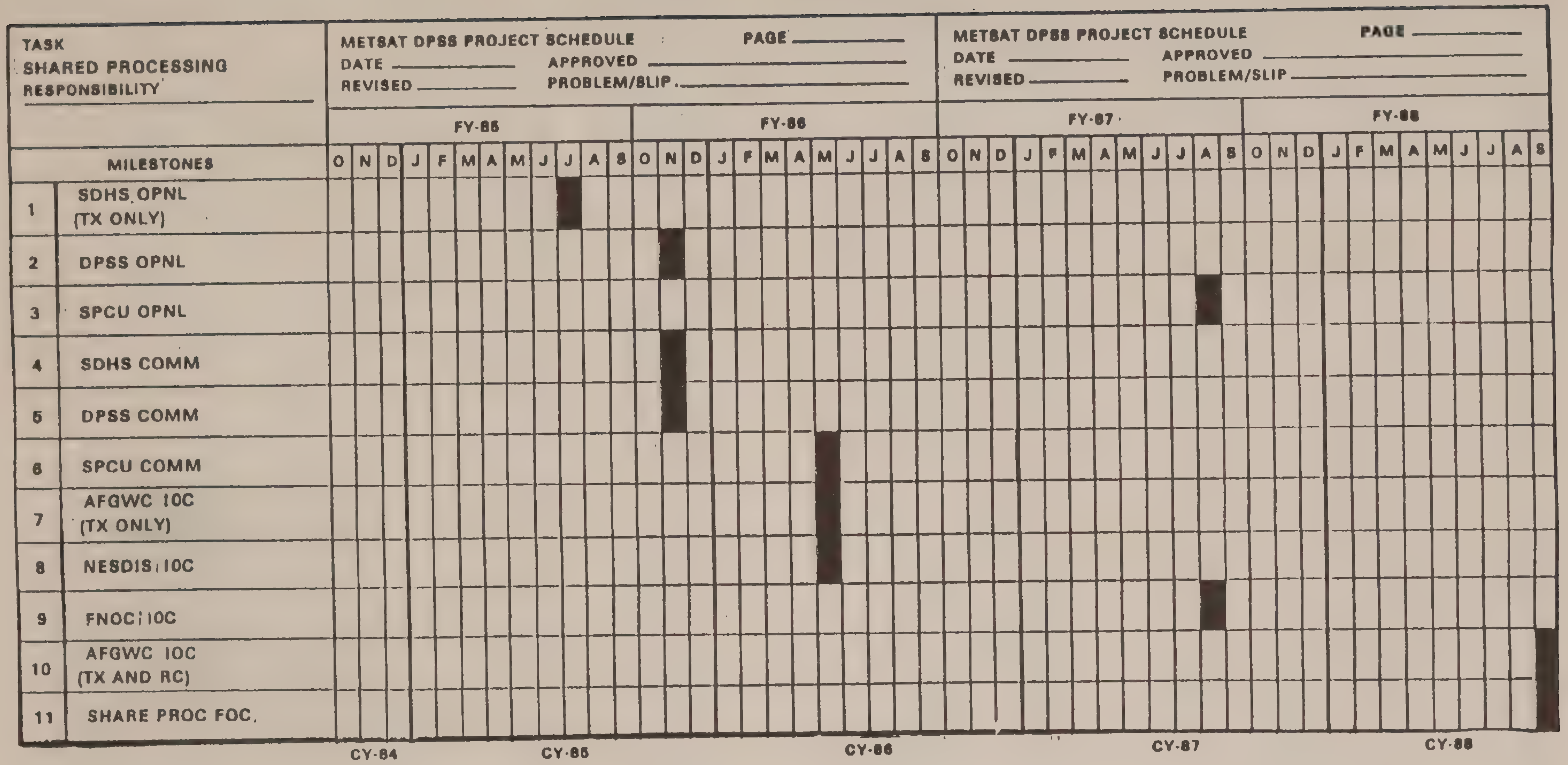
Within NESDIS, the National Climatic Data Center (NCDC) and its Satellite Data Services Division (SDSD; located in Suitland, Maryland) will be responsible for the archiving and nonoperational, retrospective, or near-real-time distribution of the above products, with the exception of the RTNEPH, which will be archived by NCDC in Asheville, North Carolina.

The current shared processing agreement also calls for the exchange of sensor data and products from the Navy Remote Ocean Sensing System (N-ROSS). N-ROSS will have a flight mission in 1990, and will measure surface winds with a NASA-furnished scatterometer, ice concentration with an SSM/I, sea-surface temperature with a low frequency microwave radiometer, and ocean waves, eddies, and fronts with an altimeter.

D. IMPLEMENTATION SCHEDULE

Figure X-2 shows the major events and dates for the implementation of shared processing. The first three milestones define the "ready-date," or operational status, for each center to support shared processing. These dates are driven by the current computer upgrades at each center. Note that AFGWC and NESDIS are scheduled for Domsat service in November 1985, at which time these centers will go on-line with initial data exchanges. Milestones 7, 8, and 9 indicate the IOC. AFGWC will not have a receive capability until 1988, at which time shared processing will have completed 2 years of operations, system evaluation, improvements, and corrections. September 1988 is planned as the final operating capability (FOC) for shared processing.

DEC 10 1984



SDHS - SATELLITE DATA HANDLING SYSTEM (AFGWC)
DPSS - DATA PROCESSING AND SERVICES SUBSYSTEM (DPSS)
SPCU - SATELLITE PROCESSING CENTER UPGRADE (FNOC)
IOC - INITIAL OPERATING CAPABILITY
FOC - FOC-FULL OPERATING CAPABILITY
TX - TRANSMIT
RC - RECEIVE

Figure X-2
Shared Processing Master Schedule

XI. ROLE OF OLS AND AVHRR IN NONMETEOROLOGICAL APPLICATIONS

A. OLS

The military performs a wide variety of nonmeteorological applications using DMSP OLS data. Most of these applications are peculiar to the military mission, such as sea surface temperature analysis in support of anti-submarine warfare (ASW). Additionally, DMSP non-real-time imagery is available for non-DOD use since it is archived by the NESDIS and is therefore in the public domain. Many public agencies have obtained the DMSP imagery from the archive to conduct research projects, such as studying volcanic eruptions.

1. Oceanography

a. Sea Surface Temperature (SST) Data. Most of the DMSP direct readout sites that acquire over-ocean coverage prepare specially enhanced DMSP OLS imagery for SST analysis. Either 0.3 nmi or 1.5 nmi resolution IR imagery is used, depending on other mission requirements. The imagery is enhanced and expanded to bring out ocean temperature gradient details by concentrating the 256 available gray shades in the imagery over the temperature range of the ocean. The enhanced imagery depicts a high degree of contrast for small changes in ocean temperature.

b. SST Applications

Anti-Submarine Warfare (ASW). The U.S. Navy routinely applies DMSP imagery in support of ASW operations (specific details of application are classified). In particular, the analyst uses SST imagery to identify:

- Oceanographic Fronts and Eddies. Fronts are features of the upper layers of the oceans and are located at the boundaries between water masses of different density. Normally associated with ocean currents, meanders in these fronts occasionally break off, becoming rotating features called eddies. Both fronts and eddies may reflect changes below the sea surface of various parameters including sound propagation, the understanding of which is important to anti-submarine warfare. These features are identified from infrared imagery and to a minor degree from sunglint patterns of visible imagery.

  The Navy uses DMSP and AVHRR imagery to analyze for ocean fronts and eddies. The Navy uses these data to chart the positions of major ocean currents, such as the Gulf Stream and the Kuroshio Current, and then operationally uses them in its Optimum Track Ship Routing (OTSR) system. The OTSR system routes ships to avoid severe weather and to take advantage of favorable currents. This system has saved the Navy many millions of dollars in reducing storm damage to ships at sea and in fuel savings.

- Water Mass Boundaries. While fronts and eddies are mostly confined to continental margins, water mass boundaries in large open-ocean areas are of importance to anti-submarine warfare with the same analysis techniques used.

- Upwelling. Upwelling in a body of water is a process by which colder, subsurface water rises toward the surface. Occurring in both coastal and oceanic areas, the resultant oceanographic front is of importance to anti-submarine warfare with the same analysis techniques used. Areas of upwelling are likely areas of fog formation, where reduced visibilities can affect ship and flight operations.

Project Gamefish. This study was conducted by the U.S. Department of Fisheries as an aid to the depressed charter fishing industry along the U.S. coast of the Gulf of Mexico. The purpose of the study was to identify regions in the northern Gulf of Mexico where the best game fishing could be found. This enabled the charter fleet to operate in the best fishing areas, which improved the fleet's business and revenues. The Air Force prepared enhanced DMSP imagery, analyzed the imagery for areas of upwelling, and provided the imagery to the U.S. Department of Fisheries. Upwelling caused plankton to rise to the surface, which attracted small fish. Since small fish are the foodstuffs of large game fish, the upwelling areas proved to be the best sports fishing areas.

New Orleans Super-Container Port Study. A study was accomplished by Louisiana State University to determine the feasibility of building a port at New Orleans for super-container ships. By using specially enhanced DMSP IR and visible imagery, it was determined that a "river" of mud was moving at 3 to 4 knots along the Louisiana coast. The effect of this "river" was that pilings for the port could not be set accurately, so no port was built.

Miami Beach Pollution Study. Miami, Florida, was dumping sewage into the Atlantic Ocean. DMSP enhanced imagery was used to determine that when anticyclonic flow developed in the ocean currents, the sewage was pushed back onto the beaches. DMSP imagery provided information that enabled the sewage pump operators to turn off the pumps at the first sign of anticyclonic flow. Thus, damage to the beaches was reduced.

Ocean Experiments. For the past several years, enhanced DMSP imagery has been routinely used to support ocean experiments (details unknown) for the Office of Naval Research, University of California. The imagery is used to determine sea surface texture and possible anomalies.

Korean Airlines (KAL) 007 Incident. When the U.S.S.R shot down KAL 007 north of Japan in the early 1980's, rescue/ salvage teams could not locate the wreckage after numerous attempts. To aid in the search efforts, a tactical DMSP site used enhanced DMSP imagery to analyze SSTs and ocean currents. The analysis was used to determine the direction in which the wreckage drifted. The prediction proved correct, and Navy search teams found the wreckage.

2. Hydrology

a. Ice Monitoring. The detection and monitoring of sea, river, and lake ice are of vital importance to military operations. Visible DMSP imagery that has been enhanced and expanded provides an invaluable and comprehensive source of information for identifying ice formation and coverage (fig. XI-1). Icebergs calved off ice shelves and floes can pose a danger to ship operations, while the growth and extent of pack ice can have an impact on Navy fleet and support functions. In addition, anomalous acoustical propagation occurs at and under the edge of an ice field, and has a significant effect on ASW operations. Furthermore, the Army requires information on ice coverage over rivers, lakes, and coastal regions. The information is used to determine trafficability for Army personnel and equipment. In Korea, for example, AWS meteorologists provide routine briefings to various Army agencies on ice coverage on rivers along the DMZ and in bays in the Yellow Sea. Another pertinent example is support to operations in Alaska. The Alaskan Forecast Unit provides a weekly briefing to the Alaskan Air Command (AAC) staff on the location, extent, and type of sea ice in the Bering Sea and Arctic Ocean. This support is especially critical during the annual cool barge season, which runs from April to August. Cool barge is the AAC resupply operation that provides a majority of the fuel, building supplies, nonperishable foods, and oversized cargo to four of the Alaskan long-range radar (LRR) sites plus the King Salmon and Galena alert bases.

b. Flood Mapping. During periods of heavy rain or during the spring thaw, enhanced and expanded visual DMSP imagery can define the boundaries of flooding. In Alaska, for example, DMSP imagery is used to identify ice jams on the major Alaskan river systems during the spring season. The jams cause major flooding in civilian communities along the Yukon River, and have threatened the F-15 alert base at Galena Air Force Station. The Alaskan Forecast Unit (AFU) at Elmendorf AFB provides a daily briefing to the AAC staff during this season on river flood potential throughout Alaska. AAC can also be asked by state authorities to support civilian communities in rescue and relief missions.

c. Snow Cover. Enhanced visible DMSP imagery is a comprehensive source of data to delineate regions covered by snow. This information is used to determine trafficability for Army personnel and equipment. AWS meteorologists routinely brief various Army agencies in Korea and Europe as to the extent of snow cover in mission operational areas. This information is also applied to search and rescue operations. For example, in Alaska the AFU uses DMSP imagery to forecast, monitor, and brief the AAC Rescue Coordination Center (RCC) on rescue operations across the theater. During the winter months when new snow accumulations can cripple rescue efforts, DMSP imagery is often the only forecast tool in the data-sparse state. A good example of this support was evident during the search for a downed SAC RC-135 that had disappeared in the mountains near Valdez, Alaska. DMSP imagery became the basis of daily search and rescue go-no go weather decisions. A bad forecast could have cost several lives and aircraft. DMSP data are also used to assist the RCC in supporting numerous civilian missions, especially in the fall when most search and rescue operations occur.

3. Volcanic Eruption Monitoring

Meteorologists at the tactical DMSP sites and at AFGWC constantly monitor DMSP imagery for volcanic eruptions and ash clouds. Enhanced infrared DMSP imagery provides an excellent tool for identifying above-ground eruptions and ash cloud movement and, on occasion, underwater eruptions. Information on the extent and movement of the ash cloud is extremely critical for safe aircraft operations near and downwind from the erupting volcanoes. AFGWC, being a centralized support facility, provides volcanic ash cloud position forecasts to all DOD agencies requiring support. AFGWC develops an ash cloud trajectory forecast based on observed conditions from the DMSP imagery in combination with upper-level wind forecasts for the area of concern. This trajectory forecast provides a prediction of ash cloud movement at several levels in the atmosphere, and is disseminated to other weather units. These units then brief DOD agencies on the aviation flight hazards. Additionally, a tactical DMSP site in the western Pacific monitors volcanic ash clouds in the region and forwards pertinent information to the Land Sciences Branch of NOAA/NESDIS. Some typical examples of volcanic eruption monitoring, reported by various Air Force units, are described below.

a. Alaska Region. Volcanic activity along the Aleutian chain and southern Alaskan range makes DMSP imagery extremely valu-

Figure XI-1
DMSP Polar Ice Imagery

DMSP Polar Ice Imagery

able to flight operations over the Pacific Ocean and southwest Alaska. Rapid eruption identification and fallout forecasts are the key to safe air travel through this area. Mt. Pavlog and Mt. Veniaminof, two of the more active volcanoes, erupt bimonthly and have visible smoke plumes 90 percent of the time. In the past 5 years, military flights to Japan have had to be rerouted on an average of three times per year due to volcanic cloud plumes at flight level.

b. Hawaii Region. DMSP imagery was used extensively during the Mauna Loa volcanic eruption on the island of Hawaii, in 1984. University of Arizona geologists, under a grant from NASA, were ecstatic, claiming it was the "first time a planetary eruption was documented from beginning to end." The IR imagery clearly delineated the large lava flows. The DMSP data were archived and eventually approved for release to geologists from the University of Arizona, the University of Hawaii, the Smithsonian Institution, and the Department of the Interior Geological Survey Team from the Cascades Volcanic Observatory (Washington). Most scientists were interested in the lava flow pattern. Others studied the dispersion of volcanic dust and ash that appeared in the DMSP visual imagery.

c. Western Pacific Region. The Clark AB, Republic of the Philippines, DMSP site constantly monitors all metsat data received for volcanic eruptions. In the past 3 years, four volcanic eruptions have been identified: one in southern Luzon, two in Indonesia, and one south of Japan. When an eruption is identified, metsat data are used to identify volcanic ash flight hazards for aircraft transiting the eruption area.

4. Auroral Oval Mapping

The auroral oval (aurora borealis and aurora australis) is mapped, and can only be viewed, using DMSP nighttime visible imagery. The equatorward boundary of the auroral oval locates the region where there are significant variations in electron density. Any electromagnetic wave that must transverse this region will suffer significant refraction, absorption, and/or irregular propagation. This, in turn, can affect operation of the DOD's Ballistic Missile Early Warning System, and can cause high frequency propagation problems for communications. Thus, knowing the location of the auroral oval is of great importance to aircraft missions, radar surveillance, and other critical DOD functions (fig. XI-2).

5. Miscellaneous

a. Missile Launch/Tracking Support. Visible and IR DMSP imagery are routinely used to monitor the extent and location of cloud cover and precipitation in the missile impact area in the western Pacific Ocean. Missile launch control authorities require this information to make go-no go decisions on missile launches, and to determine their ability to track the missiles.

b. Naval Operations. In addition to the previously discussed application of SST data, the U.S. Navy analyzes oceanic areas on the DMSP imagery for the following features:

Internal Waves. Internal waves are a wave phenomena in the ocean that form between subsurface water layers of varying density. Surface wave manifestations of internal waves have been observed in visible imagery, notably in sunglint areas under calm wind and sea conditions. Internal waves can have a disruptive influence on underwater sound propagation and on submarine operations.

Heavy Surf. Important to amphibious operations, breaking surf concentrates large numbers of condensation particles into the atmosphere. This can be detected using anomalous gray shade patterns in visible imagery.

Sea State and Variations of Sea State. Calm and rough seas are observed in visible imagery in areas of sunglint. This is important to various surface ship operations.

Oil Spills and Slicks. Assisting in the forecasting of drift patterns of oil spills and slicks, and their impact on coastal areas, these features can be detected in visible imagery using either anomalous gray shade or sunglint patterns.

River Outflows. In various operations, it is useful to know the extent of either river discharge plumes, which can be found on infrared imagery, or river outflow sediments. Such information can be gained using anomalous gray shade patterns in visible DMSP imagery.

Low-Level Aerosols and Moisture. This encompasses a wide range of features including sand, dust, smoke, air pollution, volcanic activity, damp haze or small-unresolvable cloud elements, light fog, mist and haze generated by high seas, areas of stratus/fog band dissipation, and moisture in tropical areas. The resulting reduced visibilities in these phenomena impact on a wide variety of naval operations, including flight operations. These features are detected from anomalous gray shade patterns in visible DMSP imagery.

c. Intelligence Operations. During RIMPAC 84, a large-scale, multination, joint forces exercise conducted in June 1984 in the eastern/central Pacific, visible DMSP imagery was used by Naval Intelligence to locate the position cf two aggressor

Figure XI-2
DMSP Nighttime Visible Imagery of the Aurora

DMSP Nighttime Visible Imagery
of the Aurora Borealis

aircraft carrier fleets enroute from mainland ports. Ship trails and the disruption to low-level cloud formations were very evident from visible DMSP imagery. Naval reconnaissance sorties were very successful in utilizing the imagery to locate suspected targets.

d. Space Shuttle Support. Visible and IR DMSP imagery is routinely used to support Space Shuttle operations and research. Besides providing essential cloud cover information for the launch area and the emergency landing and recovery bases, selected DMSP sites provide NASA with specially enhanced DMSP imagery that delineates sea surface temperature gradients.

e. Forest Fire Detection. DMSP visible imagery is an important source of data for the detection of forest fires. The active burn area, as well as the extent of the smoke, can readily be identified on the imagery. Search and rescue agencies can apply this information to determine how the fire and smoke will affect their operations (fig. XI-3).

B. AVHRR

1. Agricultural Uses of AVHRR Data

a. Need for Agricultural Monitoring. We live in an interdependent world. The fluctuating production of agricultural commodities in one location impacts the economy of agricultural producers on the other side of the globe. Regional food shortages attributable to drought, flood, pests, and disease cause suffering and famine and require a response from those more fortunate.

Information concerning the location, quantity, and quality of agricultural production is of use in stabilizing commodity prices. Advance knowledge of production can have large-scale social, political, and economic consequences. Remote sensing has long been viewed as a useful tool for providing needed information concerning agriculture. The development of the Landsat system was predicated, in part, on its potential usefulness for vegetation assessment. Major projects such as the Large-Area Crop Inventory Experiment (LACIE) and the joint program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) combined multiple agencies and several remote-sensing systems to assess agricultural vegetation.

b. AVHRR Observations of Vegetation. One of the most significant developments from the Landsat MSS was the use of the visible and near infrared bands for monitoring the health and vigor of vegetation and crops. The visible and near infrared channels on the AVHRR, channels 1 and 2, respectively, make observations in similar spectral bands as those on the MSS used for vegetation monitoring. The advantage of NOAA satellites for monitoring green vegetation is that they provide daily observations, while Landsat has a revisit time of 16 days. If the area of interest is frequently cloudy, large gaps can occur in the Landsat coverage. The improved temporal coverage for NOAA is an important advantage, but obtained at the price of lower resolution data.

AVHRR channel 1 observes in the 0.55 to 0.68 micrometer spectral region, and channel 2 covers 0.73 to 1.1 micrometers. Green vegetation has a reflectance of about 20 percent in the channel 1 spectral region, but up to 60 percent in the channel 2 part of the spectrum. Other features viewed from space, such as bare ground, water, snow, and clouds, have similar reflectances in the two bands, or a greater reflectance in channel 1 than channel 2. Various mathematical combinations of channels 1 and 2 radiances are correlated with the density and greenness of vegetation. The most commonly used indices are the Vegetation Index (VI) and the Normalized Vegetation Index (NVI), which are computed from the equations:

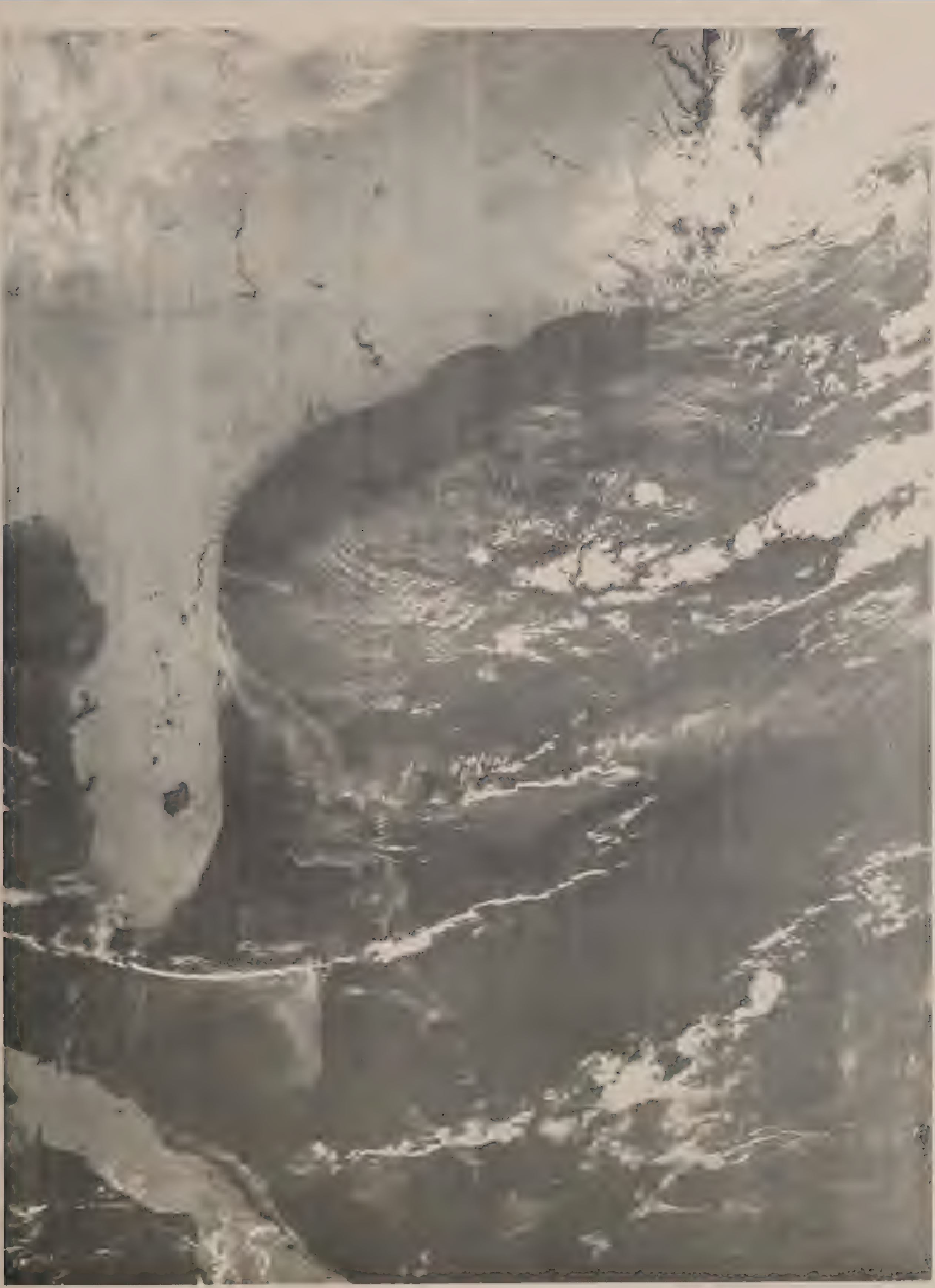
$$VI = Ch_2 - Ch_1 \text{ and } NVI = (Ch_2 - Ch_1)/(Ch_2 + Ch_1)$$

The NVI is preferred because it partially compensates for changing illumination conditions, surface slope, and viewing aspect.

Two Vegetation Index products are being developed for agricultural monitoring. One provides a global sampling of vegetation indices on a daily and weekly basis; the other is a target-type Vegetation Index calculated on a USDA grid. Global Vegetation Index images are made from AVHRR channels 1 and 2 data obtained from GAC recordings, which are mapped each day into 1,024 by 1,024 polar stereographic arrays (one each for the Northern and Southern Hemispheres). Resolution in the mapped arrays ranges from 15 km at the Equator to 30 km at the poles. The current mapping algorithm maps all pixels, replacing previously mapped pixel values with the latest one, so that the value remaining in the cell is the last pixel that mapped to each cell. This procedure is randomized somewhat by day-to-day jitter introduced by D+10 km error in Earth location accuracy.

Atmospheric effects (e.g., scattering by aerosols, Rayleigh scattering, and subpixel-sized clouds) all act to increase Ch_1 with respect to Ch_2, and reduce the computed Vegetation Indices. The reduction is greatest at high scan angles. To eliminate cloud contamination and atmospheric effects as much as possible, the daily mapped arrays are composited over a 7-day period by saving the channel 1 and 2 values at each array location for the day with the maximum observed Vegeta-

Figure XI-3
DMSP Imagery of Forest Fire Smoke off the
East Coast of Central Florida



DMSP Imagery of Forest Fire
Smoke off East Coast of Florida

tion Index during the compositing period. This type of maximum value compositing eliminates off-nadir observations and hazy days in favor of straight down, clear-column observations.

A second product under development is a target-type Vegetation Index. The grid resolution required for this polar stereographic product ranges from 30 km at the Equator to 60 km at the poles. This product is not done globally, but only for the United States and agriculturally important areas of the U.S.S.R. and South America. The target VI is a daily average index calculated from all GAC pixels that pass a threshold-type cloud screen. There are two thresholds tests. One is low threshold, designed to screen out partially cloud-filled pixels. A second, brighter threshold is designed to identify the presence of significant clouds in the target. If the target contains significant clouds, the VI from the target, even though computed from cloud-screened pixels, may be contaminated. The daily indices are composited for the maximum VI over a 7-day period to eliminate cloud-contaminated or off-nadir observations.

The USDA is currently using Vegetation Indices calculated from LAC data with a repeat observation cycle of 7 to 9 days. The target-type Vegetation Index product is an experiment to determine if daily looks with 4 km GAC data are more effective at obtaining a cloud-free estimate of VI than the less frequent LAC observations. (See explanation on limitations of LAC observations in chapter IV of this report.)

c. Applications. Some of the current uses of VI products derived from AVHRR data are discussed in the following paragraphs.

Supplement to Existing Methods. Currently, assessment of environmental impacts on foreign agriculture primarily uses rainfall and temperature information relative to historical normal values for the region of interest. As available, a variety of ancillary information such as newspaper or diplomatic reports may also be incorporated. In no case is the quality and quantity of information equal to that for the United States. It may be very sparse in some foreign regions.

In such circumstances, the AVHRR satellite products, even in their current experimental form, have the potential for augmenting available sources of information about foreign agriculture. The Vegetation Indices are known to be related to the amount and condition of vegetation in the scene viewed. The most useful satellite products are time history plots of Vegetation Indices averaged over agricultural regions of interest. The time history plot of the Vegetation Index for the current year in a region is compared to that for a previous year or years. Such comparison can reveal significant trends in the reflectance of vegetation. If the actual conditions that prevailed in the baseline year of the time series are known, even generally, the environmental conditions in the current year can be evaluated with reference to the baseline year.

Comparison of Vegetation Indices to assess crop stress works best in regions where a reasonable number of cloud-free days occur during the crop seasons. These include most of the major wheat, corn, and soybean areas of the globe. In regions where cloudiness is almost continually present to some degree, such as Central America and Southeast Asia, comparisons of time history plots are difficult. In these cases, however, a good deal of useful information is still available from the satellite data. Here, the same general degree of cloudiness as the baseline year probably implies similar levels of rainfall, and an extended clear period could signal excessively dry conditions.

Wildfire Management Program. A joint project conducted by the U.S. Geological Survey's Earth Resources Observation Systems (EROS) Data Center, the Bureau of Land Management (BLM), and NOAA has evaluated the use of AVHRR data as an input into BLM's national wildfire management program. A normalized difference Vegetation Index was calculated for three study sites in northwestern Arizona for 5 days in March and April of 1982. Cloud-free AVHRR-LAC digital tapes were acquired from the Redwood City, California, NOAA facility. They were received by the EROS Data Center within 1 week of satellite overpass, and were geographically registered to a 1 by 1 km Albers Equal Area projection grid using 28 control points.

This study found that the derived Vegetation Index corresponds to the fire fuels measured on the ground by field personnel, and could be used to identify areas that were highly susceptible to wildfires in 1982. It was concluded that the information content of the AVHRR data provided district fire management personnel with the capability of (1) detecting, locating, and ranking areas according to the buildup of fire fuels and risk of wildfires; (2) estimating time of senescence of the herbaceous vegetation for use as an indicator of when fire problems will increase; and (3) identifying regions of higher risk of wildfires so that fire equipment can be strategically located to maximize its utility. The BLM now uses AVHRR data operationally in the western United States to provide estimates of fire danger.

2. Hydrology

a. Continental Snow Cover Mapping. Since November 1966, NOAA has prepared the Northern Hemisphere Weekly Snow and Ice Cover

Chart. These charts show the areal extent of continental snow cover, but do not indicate snow depth. The analysis is based on NOAA polar-orbiting visible-band satellite imagery. The snowline represents the latest cloud-free image of that particular area of the world. NOAA polar-orbiting satellite data are used because they provide global coverage of the Earth's surface. The visible band is useful for mapping snow because it provides the best contrast between snow and nonsnow areas. The Northern Hemisphere snow cover charts are operationally digitized by NOAA and stored on computer tape. From the digitized data, monthly, anomaly, frequency, and climatological snow cover maps can be created. In addition, continental or regional snow cover areas can be calculated over a long time series.

b. River Basin Snow Mapping. Snow depth and snow-covered area are two important parameters that determine the extent of water runoff in river basins. In many parts of the world, this runoff is important for drinking water supplies and irrigation. The NOAA geostationary and polar-orbiting satellites cannot be used to determine snow depth, but they can be used to determine the snow-covered area in a river basin. Snow maps are produced by enlarging and rectifying a visible-band image to match the selected river basin map. Registration of the image to the map involves aligning physiographic landmarks, such as lakes and rivers, using an optical rectification device. The rectified satellite image is overlayed on the river basin outline. The analyst then traces the snowline from the satellite image onto the appropriate basin map. Snow-covered areas can be shaded, making it easy to calculate electronically or manually the percentage of snow-covered area in the basin.

c. Flood Extent Mapping. Floods have resulted in death and destruction throughout history, although construction of flood-preventing structures helps to protect lives and reduce losses. Annual flood losses in the United States often exceed $1 billion. Economics dictates that engineers and government officials be given improved information on the location of flood hazard areas and the assessments of the areas of inundation when floods occur. Operational NOAA polar-orbiting satellites are a source of this information, and have been used in studies for the 1973 Mississippi River floods, the 1978 Kentucky River floods, and the Red River of the North floods of the same year. In each case, the flooded areas showed up best on the 1 km resolution nighttime thermal infrared imagery because of high land/water temperature contrasts. Recently, operational monitoring of flood extent using NESDIS satellite data was done in support of the National Weather Service River Forecast Centers during the Illinois River flood of December 1982 and the Pearl River flood of April 1983.

d. Ice Monitoring. NESDIS began producing operational ice analyses of the Great Lakes using NOAA polar-orbiting data during the 1973-74 ice season. Ice analyses were produced twice weekly and disseminated via facsimile and mail. Presently, the Great Lakes Ice Analysis, except for Lake Ontario, is produced by NWS at Ann Arbor, Michigan. The ice analysis is then transmitted to the Navy/NOAA Joint Ice Center (JIC) in Suitland, Maryland. The JIC updates the NWS ice analysis with the latest satellite data, analyzes the ice conditions in Lake Ontario, and then disseminates the analyses to the user via facsimile.

The NWS Central Region is the largest user of the Great Lakes ice analyses. The Central Region has responsibility for forecasting ice conditions in each of the Great Lakes, and the Great Lakes ice analyses are used as input to the ice forecasts. The ice analysts and ice forecasters use the satellite imagery and ice analyses to aid in the routing of ships in the Great Lakes. The research community also uses the satellite imagery and ice analyses. With more than 10 years of high-resolution NOAA polar-orbiting satellite data available, and many years of aerial reconnaissance and ship reports, ice climatologies of the Great Lakes have been produced by NOAA.

e. Lake Surface Water Temperature. Great Lakes surface water temperature analyses have been produced operationally using AVHRR data since August 1975, during the ice-free season, which usually occurs between April and December. After a cloud screening process, a computer processes the calibrated brightness temperature and generates a printout of surface temperature values at a spatial average of 5 km. A multichannel technique is employed using the two thermal channels to correct for atmospheric attenuation and to convert brightness temperatures to surface water temperatures. The GOES satellites do not have the two thermal channels necessary to employ this technique; that is why the polar-orbiting satellite data are used. Buoy data are used as ground truth for the satellite data. Generally, the satellite-derived temperature data are within D+0.6 °C rms of the buoy temperatures.

The Great Lakes surface water temperature analysis is produced twice weekly during the ice-free season, and is distributed by facsimile and mail. Presently, the analyses are used by the NWS in the Central Region. Forewarning of storm conditions by NWS offices on the Great Lakes is critical to safety. Therefore, a knowledge of lake water temperature is an important factor, especially in the months from late September to December when cold air outbreaks are influenced by the relatively warmer water. In addition, accurate surface water temperatures are major inputs into the prediction of ice formation, growth, and dissipation during the early winter and spring transition periods. Other applications include search and rescue operations, when hypothermia of accident victims is a major concern, lake circulation research, heat budget analysis, and the effect of the lake on thunderstorms, a prime hazard to recreational boaters.

3. Other Land Applications

a. Volcanology. Because of their global and frequent coverage, the NOAA polar-orbiting satellites are excellent platforms for observing volcanic eruptions, especially in remote parts of the world. The GOES geostationary satellites are also good platforms for monitoring volcanic eruptions between 55° N. and 55° S. due to their half-hourly image production. One of the first documented uses of NOAA polar-orbiting satellite data for studying a volcanic plume was for the 1976 Augustine eruption in southern Alaska. Using temperature data derived from NOAA thermal infrared imagery, it was possible to study the vertical and horizontal plume morphology and track the trajectory of the ash cloud. Recently, NOAA 6 and NOAA 7 AVHRR satellite data were used to examine the El Chichon, Mexico, eruptions of March and April 1982, and to track the subsequent stratospheric cloud associated with these eruptions. The data showed that the April 4 eruption reached an altitude between 24 and 31 km and the resultant stratospheric ash cloud took 3 weeks to circle the Earth. This was the largest and most persistent ash cloud ever detected by satellite data since the inception of such data in 1966.

In addition to their use in volcanological studies, NOAA polar-orbiting and geostationary satellite data may be useful in aviation warnings to aircraft flying near erupting volcanoes. In June and July of 1982, two Boeing 747 aircraft flew into ash clouds from the erupting Galunggung volcano in Java. Both suffered multiple engine failures and severe loss of altitude. Fortunately, safe emergency landings were made with no injuries. These near-fatal incidents have prompted the International Civil Aeronautics Organization (ICAO) to examine the possibility of using satellite data to provide ash cloud warnings to pilots when a volcano erupts.

b. Urban Heat Islands. Increased urbanization and industrialization have increased the intensity and extent of the positive thermal anomalies, commonly called urban heat islands. Urban heat islands influence precipitation patterns, snow melt, physiological comfort, cooling and heating requirements, growing seasons, and local atmospheric circulation. With the trend toward urbanization increasing, the day is approaching when large megalopolises will exert regional influences on the surrounding environment. Thermal infrared data from the NOAA polar-orbiting and geostationary satellites can play an important part in providing instantaneous and repetitive spatial and temporal information about urban heat islands. NOAA 3 data were used to perform a morning and evening surface temperature analysis for the Los Angeles area using 1 km resolution thermal data. The analysis showed that the highest morning temperatures were found over the industrial zone, and the highest evening temperatures were over the central business district and high-density residential areas. NOAA satellite data were used to detect more than 50 urban heat islands in the midwestern and northeastern United States on July 28, 1977. Two of these heat islands, Washington, D.C., and Baltimore, Maryland, yielded maximum urban-rural temperature differences ranging from 2.6 °C to 6.5 °C. A similar study detected 17 urban heat islands in New Hampshire, Massachusetts, and Rhode Island on May 23, 1978. Urban-rural temperature differences averaged approximately 5 °C.

c. Fire Detection and Deforestation. It has been shown that the use of the 3.8 thermal infrared channel onboard the current NOAA-series satellites provides the capability to detect high temperature sources such as steel plants and waste gas flares. It has also been demonstrated how this channel can be used for fire detection. One of the most interesting fires detected came from a NOAA 7 image taken over the Manaus, Brazil, area on Oct. 17, 1981. In the near-IR band, a large smoke plume was apparent. The 3.8 micrometer channel showed a large white (hot) area at the plume source, this being the active burn area. In addition, many other fires (small white areas) were also apparent near the Solimoes River and Manaus, none of which was visible on the near-IR image. The fires were a result of extensive slash and burn agriculture, timber clearing, and colonization in the area. The ability of the 3.8 micrometer channel to detect fires in remote tropical areas may prove useful for deforestation studies.

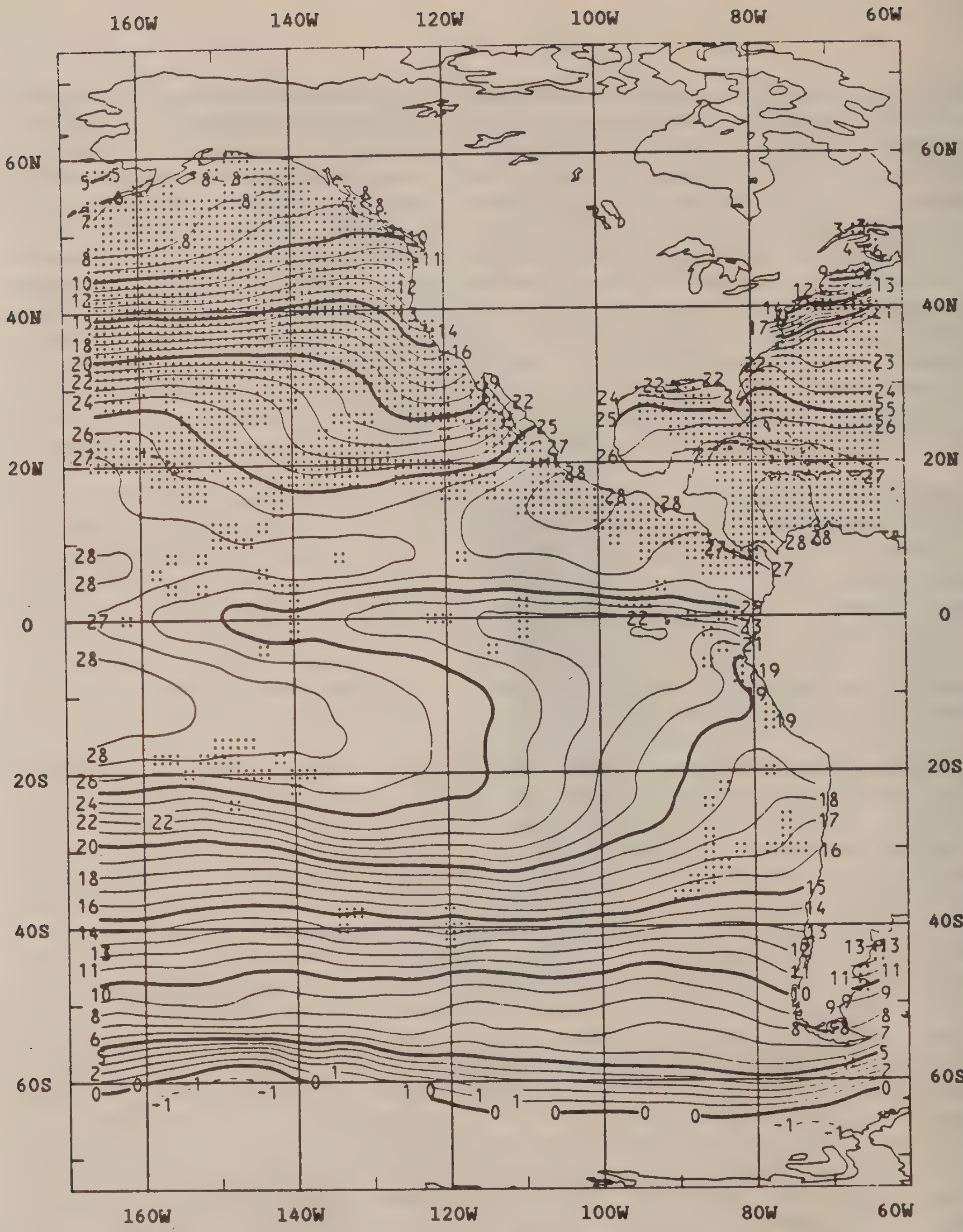
4. Oceanographic and Sea Surface Temperature

a. Operational AVHRR Oceanographic Products and Applications. AVHRR data are employed operationally to produce quantitative SST measurements. Three types of products are produced, each with unique applications. These are SST observations, SST monthly means, and SST analyzed fields.

SST Observations. An SST observation is a measurement of SST at a particular location and time. Satellite SST observations are derived by applying multichannel cloud tests and atmospheric corrections to AVHRR data. Approximately 70,000 individual measurements of SST are produced daily, covering all the world's oceans, seas, and large lakes. Although each measurement has a resolution of 8 km, the spacing between observations varies from 8 km (i.e., contiguous coverage) in the coastal waters of the United States to 25 km in the open ocean. The spacing is varied to support diverse applications: a high density to aid fishermen in coastal waters; and a lower density to achieve global coverage for climatological applications without using excessive computer disk storage. Observations of SST are produced from AVHRR data on an orbit-by-orbit basis, and then stored in a user-accessible data base every 6 hours. All satellite SST observations are transmitted to FNOC in Monterey, and are used by the Navy, along with conventional surface ship and buoy reports, to generate SST analysis for support of Naval fleet operations. The NWS also accesses the satellite observations, blending them with ship and buoy observations to produce SST charts for marine weather applications. One satellite SST observation from each 2-1/2 degree latitude-longitude square is transmitted twice daily on the GTS to the meteorological and oceanographic services of the member nations of the U.N. WMO.

SST Monthly Means. Satellite SST observations derived from AVHRR multichannel data are grouped into 2-1/2 degree latitude-longitude squares monthly in order to calculate a monthly average SST. The Climate Analysis Center of the NWS merges these satellite monthly means with ship and buoy data to form composite monthly mean SST charts (fig. XI-4) useful in long-range weather forecasting and in the monitoring of climatic events such as the periodic warming of the tropical waters of the Eastern Pacific known as El Niño.

SST Analyzed Fields. Satellite SST observations are objectively analyzed at a number of spatial and temporal scales to produce fields of SST with temperatures calculated for regularly spaced gridpoints. A global field with gridpoint temperatures separated by 1 degree of latitude and longitude (fig. XI-5) is useful as input to weather, such as determining likely tropical storm formation regions, and in forecasts of storm intensification or decay, sea fog, and cloud formation. High-resolution SST-analyzed fields are disseminated by NOAA regional weather and marine offices in the form of isotherm contour charts (fig. XI-6). These are generally contoured by hand from digital displays of AVHRR HRPT data, or from automated SST analyzed fields derived by using AVHRR GAC data (fig. XI-7). These SST charts, which depict SST patterns in the coastal waters of the United States, are sent via autotelecopier to commercial and recreational fishermen, who use them to make day-to-day tactical decisions in their search for salmon, albacore tuna, swordfish, Alaskan herring, and anchovy. They are also of use in forecasting the formation of ice, and thus in the protection of Alaskan oil well equipment and personnel, and in the prolongation of the shipping season in the Great Lakes. As input for planning purposes, they are invaluable in determining survival times in search-and-rescue activities and data collection strategy in support of physical, biological, and chemical oceanographic research cruises.


160W
140W
120W
100W
80W
60W
60N
40N
20N
0
20S
40S
60S

Eastern Pacific Ocean
SST--MONTHLY MEAN (°C)
SHIP, BUOY, and SATELLITE
DATA
NOVEMBER 1984

Monthly mean sea surface temperature is the mean of *in situ* and satellite data within two-degree quadrangles. Contour line interval is 1.0°C. the stippling indicates where the analysis was fixed by the *in situ* data; contours are not shown in areas without data.

Figure XI-4
Composite Monthly Mean Sea Surface Temperature Analysis

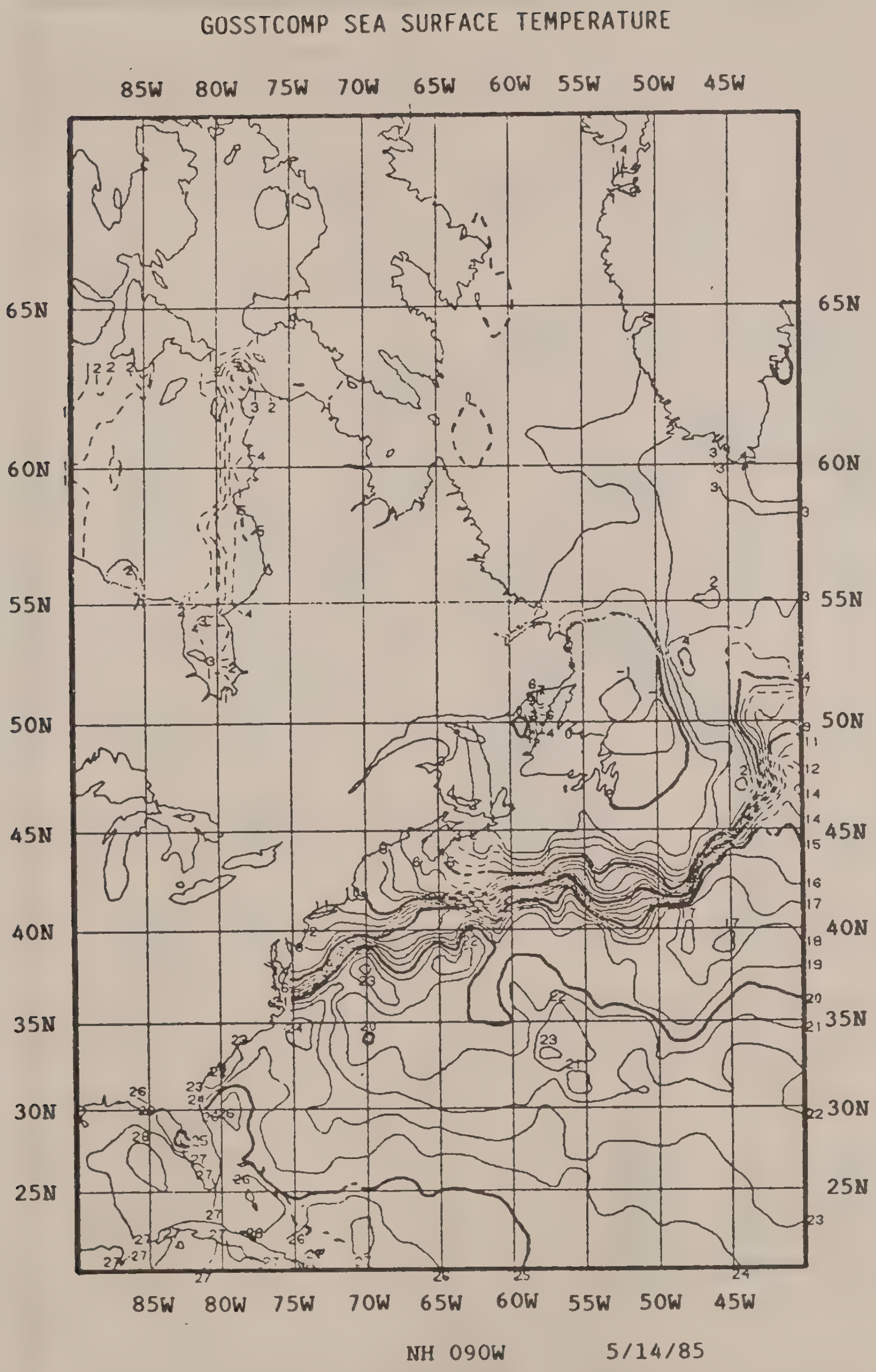

GOSSTCOMP SEA SURFACE TEMPERATURE
85W
80W
75W
70W
65W
60W
55W
50W
45W
65N
60N
55N
50N
45N
40N
35N
30N
25N
NH 090W
5/14/85

Figure XI-5
Objective Analysis of
Sea Surface Temperature From Satellite Data

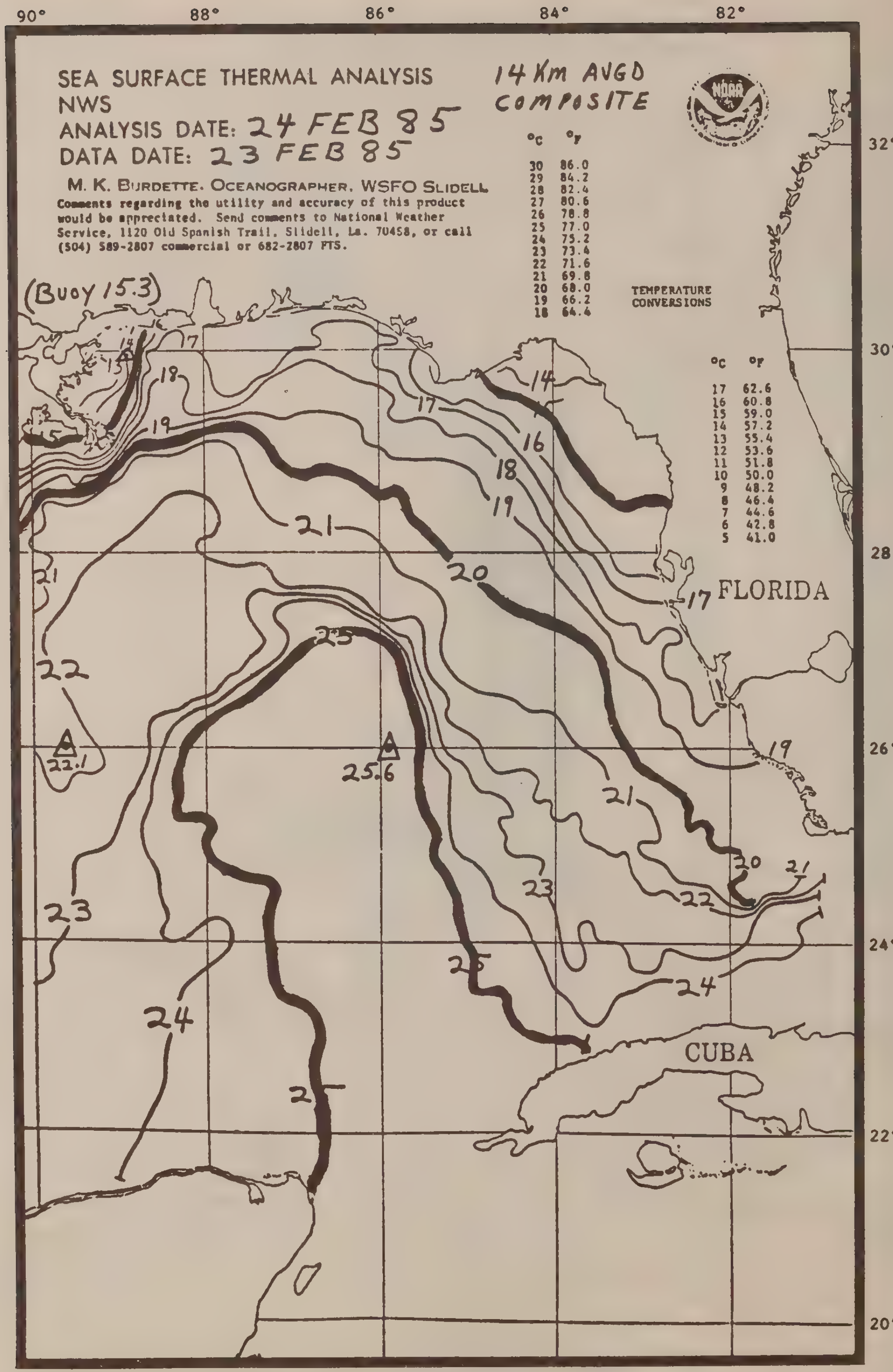

90°
88°
86°
84°
82°
SEA SURFACE THERMAL ANALYSIS
NWS
ANALYSIS DATE: 24 FEB 85
DATA DATE: 23 FEB 85
M. K. BURDETTE. OCEANOGRAPHER. WSFO SLIDELL
Comments regarding the utility and accuracy of this product would be appreciated. Send comments to National Weather Service, 1120 Old Spanish Trail, Slidell, La. 70458, or call (504) 589-2807 commercial or 682-2807 FTS.
14 Km AVGD COMPOSITE
°C °F
30 86.0
29 84.2
28 82.4
27 80.6
26 78.8
25 77.0
24 75.2
23 73.4
22 71.6
21 69.8
20 68.0
19 66.2
18 64.4
TEMPERATURE CONVERSIONS
°C °F
17 62.6
16 60.8
15 59.0
14 57.2
13 55.4
12 53.6
11 51.8
10 50.0
9 48.2
8 46.4
7 44.6
6 42.8
5 41.0
32°
30°
28°
26°
24°
22°
20°
(Buoy 15.3)
FLORIDA
CUBA
22.1
25.6
14
15
16
17
18
19
20
21
22
23
24
25

Figure XI-6
High-Resolution Sea Surface Thermal Analysis

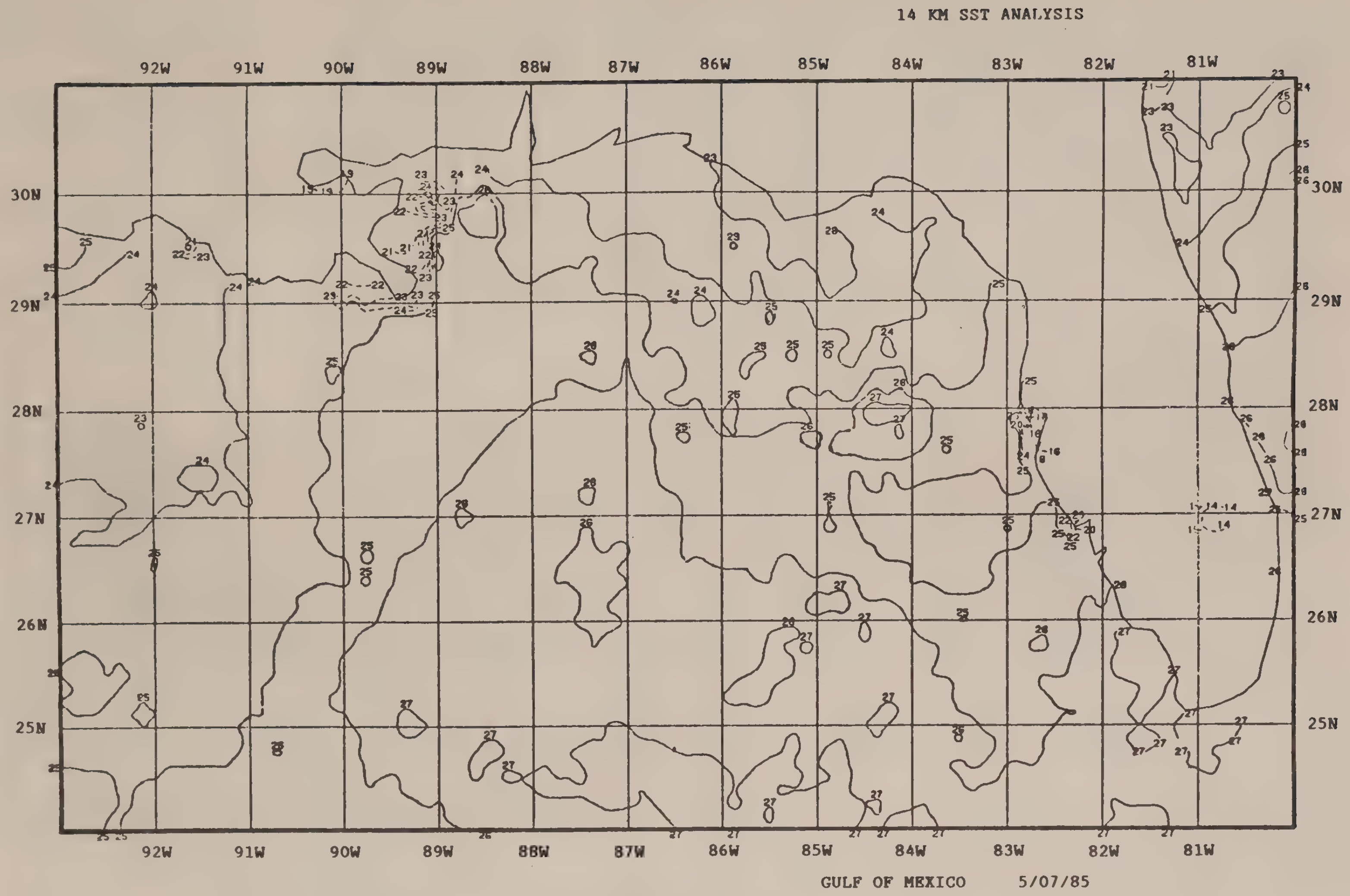

14 KM SST ANALYSIS
92W
91W
90W
89W
88W
87W
86W
85W
84W
83W
82W
81W
30N
29N
28N
27N
26N
25N
GULF OF MEXICO
5/07/85

Figure XI-7
Sea Surface Temperature Field
Analyzed From GAC (4 km Resolution) Data

Qualitative Products. Black-and-white imagery, produced from the AVHRR thermal channels, or from combinations of channels, is used to produce analyses of oceanographic features such as fronts, eddies, and currents. In the AVHRR imagery, one can recognize the surface thermal patterns of currents, such as the Gulf Stream and the Gulf of Mexico Loop Current, upwelling of cool subsurface water, such as that which occurs along the coast of California, and warm and cold eddies that are pinched off from meanders of the Gulf Stream. Thermal imagery is available to television and radio stations, weather forecast offices, fishing companies, Coast Guard stations, and private shipping companies. NOAA oceanographers and marine meteorologists interpret these images to produce charts like the oceanographic analysis shown in figure XI-8. This widely disseminated chart is valuable in making ocean condition forecasts for determination of optimum coastal marine transportation routes, and search patterns in search-and-rescue operations.

A study of the usefulness of these ocean-feature analyses was done by the EXXON Corporation. After a 7-month study, it was determined that the EXXON fleet of 15 tankers would save $945 million in fuel oil by using the NOAA Oceanographic Analysis while traveling along the U.S. gulf and east coasts. The Crowley Towing and Transportation Company of Jacksonville, Florida, which operates vessels in the West Indies and Gulf of Mexico, is experiencing savings of $120,000 per vessel per year by utilizing the Gulf Stream to the utmost to increase average speed northbound from 9.5 to 12.0 knots, and by avoiding the Gulf Stream when southbound.

Special briefings, using ocean-feature charts, are given to yachtsmen before major ocean races to aid in their course selection. The charts are utilized by the National Marine Fisheries Service for effective management of living marine resources through the estimation of year-class survival, species distribution, abundance, and migration routes. Environmental agencies use the imagery and ocean-feature analysis to determine the spreading rate and coverage of marine pollution, such as that resulting from oil spills or ocean waste-dumping activities.

In order to disseminate these charts as widely and rapidly as possible, they are distributed by a wide range of media, including NOAA Weather Radio, national facsimile, autotelecopier, NWS data networks, Coast Guard Radio, and mail. The radio broadcasts give the latitudes and longitudes of the "North Wall" of the Gulf Stream, i.e., the shoreward edge of the warm service water, which coincides closely with the maximum velocity core of the Gulf Stream.

b. Research Applications of AVHRR Data. AVHRR data are used

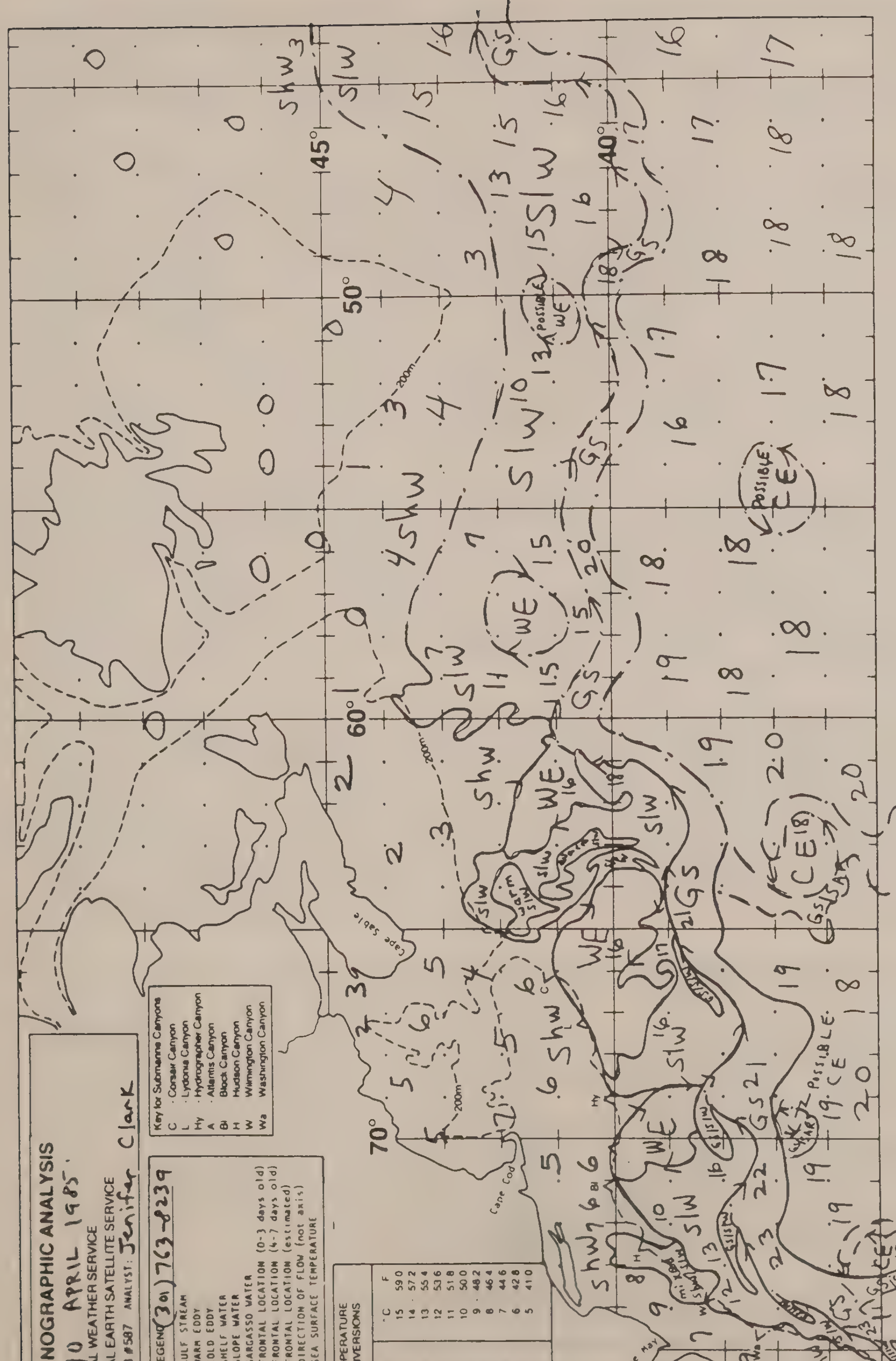

OCEANOGRAPHIC ANALYSIS
DATE 10 APRIL 1985
NATIONAL WEATHER SERVICE
NATIONAL EARTH SATELLITE SERVICE
D127 N98 #587 ANALYST: Jenifer Clark
SYMBOL LEGEND (301) 763-8239
GS GULF STREAM
WE WARM EDDY
CE COLD EDDY
ShW SHELF WATER
SlW SLOPE WATER
SAR SARGASSO WATER
FRONTAL LOCATION (0-3 days old)
FRONTAL LOCATION (4-7 days old)
FRONTAL LOCATION (estimated)
DIRECTION OF FLOW (not axis)
19 SEA SURFACE TEMPERATURE
Key for Submarine Canyons
C Corsair Canyon
L Lydonia Canyon
Hy Hydrographer Canyon
A Atlantis Canyon
Bl Block Canyon
H Hudson Canyon
W Wilmington Canyon
Wa Washington Canyon
TEMPERATURE CONVERSIONS
°C °F
27 80.6
26 78.8
25 77.0
24 75.2
23 73.4
22 71.6
21 69.8
20 68.0
19 66.2
18 64.4
17 62.6
16 60.8
°C °F
15 59.0
14 57.2
13 55.4
12 53.6
11 51.8
10 50.0
9 48.2
8 46.4
7 44.6
6 42.8
5 41.0
70°
60°
50°
45°
40°
Cape Sable
Cape Cod
Cape May
200m
shw
slw
GS
WE
CE
POSSIBLE CE
POSSIBLE WE
warm slw
mixed

Figure XI-8
Oceanographic Analysis Product

by national and international groups in oceanographic research applications. The typical activity can be illustrated by a description of several programs that utilize the AVHRR data. These are TOGA, EPOCS, SEQUAL, and a University of Miami/NOAA cooperative program.

TOGA. The Tropical Ocean Global Atmosphere (TOGA) program is an international program coordinated by the WMO that is aimed at the study of long-range climate prediction. In the United States, the NOAA Climate Office will support this climate research for a decade, starting in 1985. One of the oceanic variables used in this research program is the satellite-derived sea surface temperature. The TOGA project will utilize the operational SST products, described above, as well as the raw AVHRR data presently archived at NESDIS in digital form on computer tapes. The AVHRR tape archive is vital to the success of the overall TOGA climate research.

EPOCS. The Equatorial Pacific Ocean Climate Study (EPOCS) is a NOAA program to study the ocean climate as it is related to the El Niño phenomena. Surface and subsurface oceanic measurements have been made since 1978 in the eastern equatorial Pacific in support of EPOCS. The NESDIS satellites contributed to the discovery of seasonal 30-day oscillations of the South Equatorial Current. The AVHRR data are presently being used to monitor the El Niño events.

SEQUAL. The Seasonal Equatorial Atlantic Study (SEQUAL) is an NSF-funded program in the equatorial Atlantic, with goals similar to the EPOCS project. The AVHRR archive data are being used mainly by university research scientists supported by NSF, and by French scientists doing concurrent research in the equatorial Atlantic and on the westward movement of long (1,000 km) waves on the thermal front in the eastern equatorial Pacific.

University of Miami-NOAA Cooperative Program. The advent of AVHRR data in 1979 and the establishment of a permanent digital AVHRR archive at NESDIS have led to a cooperative research program between NOAA and the University of Miami. As a consequence of this program, NESDIS has acquired an interactive computer system from the University of Miami for processing of AVHRR data in oceanographic research applications. This capability allows the AVHRR data archive to be used retrospectively at spatial scales between 1 and 100 km. The interactive system is presently in use to support the TOGA, EPOCS, and SEQUAL projects described above.

c. Future Operational AVHRR Oceanographic Products and Applications. The period 1985-87 will be a time of major changes in the organizations involved with and the formats used for producing and disseminating NOAA operational AVHRR oceanographic products. These changes should bring substantial added benefits to the user community.

Organizational Changes. Currently, oceanographic products derived from AVHRR data are disseminated by the Information Processing Division of NESDIS, the Marine Products Branch of NWS, and the NOAA/Navy JIC (all in the Washington, D.C., area). In addition, the Navy FNOC in Monterey generates products for military applications using observations derived from AVHRR data. Also, there is a network of regional offices that produce and deliver products to local users. These are the NOAA Ocean Service Centers (OSC) in Seattle and Anchorage, and the NWS Satellite Field Services Stations (SFSS) in Redwood City (near San Francisco), Slidell (near New Orleans), Miami, Honolulu, and Washington, D.C. In the near future, the activities of these oceanographic product-generating organizations are to be standardized and consolidated. Personnel in NWS, NOS, and NESDIS with oceanographic product responsibility in the Washington, D.C., area are being brought together in the newly established Ocean Product Center (OPC), collocated with the NWS National Meteorologial Center near Washington, D.C. The NOAA Ocean Service Centers are staffed by oceanographers and marine meteorologists responsible for disseminating a wide range of oceanographic products such as marine weather forecasts, tide tables, coastal navigation charts, ocean-feature charts, ice and marine hazard warnings, etc. In 1987, responsibility for the product of global observations of SST from GAC data will be moved from NESDIS to FNOC under the shared processing agreement. In order to provide a backup capability for FNOC, and to provide high-resolution SST data along the U.S. coasts, NESDIS will develop the capability of producing 2 km SST observations from HRPT data. If all of the above organizational changes take place as planned, the flow of AVHRR data and the generation of products from these data will look something like this:

- AVHRR raw data will be received by both NESDIS and FNOC.

- FNOC will produce global SST observations from AVHRR GAC data, transmit the observations to NESDIS, and use them to produce oceanographic products for military applications.

- NESDIS will receive global SST observations from FNOC, calculate high-resolution SST observations for U.S. coastal regions from AVHRR HRPT data, and store both types of observations in a user-accessible SST observation data base.

- The OPC will generate national oceanographic guidance products for civilian applications from both the global and high-resolution SST observations and transmit them to

NOAA regional centers. These centers will use the guidance products as input, and will add knowledge of local conditions derived from experience and local environmental data in order to produce regional oceanographic products tailored to the needs of local marine users.

Product Generation Changes. The current operational AVHRR oceanographic products will be enhanced during the next 3 years. Changes that have been planned include:

- Deriving SST observations from HRPT data for the coastal waters of the United States at a resolution of 2 km (this will represent an increase in resolution from the current 8 km resolution of GAC SST observations)
- Increasing the resolution of global SST analyzed fields from 1 to 1/2 degree of latitude and longitude
- Increasing the resolution of SST monthly means from 2 to 1 degrees of latitude and longitude
- Increasing the resolution of local-scale SST analyzed fields for the U.S. coastal regions from 1/8 to 1/32 degrees
- Implementing interactive techniques of producing SST and ocean-feature charts from full-resolution (1.1 km) AVHRR HRPT data for use by the OSC and OPC

XII. FUTURE MISSION REQUIREMENTS

A. FUTURE DMSP REQUIREMENTS

DOD meteorological satellite data requirements are documented in Defense Meteorological Satellite System (DMSS) System Requirements Document (DMS-10C), Dec. 14, 1983.

The current DMSP Block 5D-2 system will evolve into the improved Block 5D-3 satellites. Six 5D-3 satellites (S-15 through S-20) will be launched on Titan IIs from FY90 to FY98, to be followed by the STS-optimized DMSP II. Block 5D-3 improvements will include hardening against high-energy laser attack, increased power and battery capability resulting in a 42-month mean mission duration in any orbit, increased payload capability, autonomous ephemeris generation, and momentum unloading.

Meeting more of the validated requirements not currently being met may require an increase in the number of satellites or a change in orbital elements to include a geosynchronous orbit.

B. FUTURE POES REQUIREMENTS

Since launching the first meteorological satellite, TIROS I, on April 1, 1960, the United States has maintained in orbit an array of spacecraft in support of weather forecasting and for monitoring natural environmental hazards. Following the first TIROS, NASA supported the development of a series of Nimbus experimental remote-sensing spacecraft for weather observations, which served as test vehicles for ever-more-advanced sensors. As spacecraft advances and ground station processing reached a stage permitting quantitative analysis of remote-sensing data, research satellites gave way to operational, NOAA-series platforms.

The current generation of U.S. polar meteorological satellites began with the launch of NOAA 8 (E) in 1983. (NOAA-series spacecraft have letter designations before launch and are then numbered when operational in orbit.) The same family of platforms will continue through NOAA J, slated for launch in March 1989. In a procurement of three more spacecraft, NOAA K, L, and M, small changes in the space platform are planned to support several significant changes in instrumentation. After NOAA K, L, and M (1990-92), a thorough redesign of the space platform is projected, accompanied by an increase in the number of sensors carried to include modified versions of the present sensors and also experimental sensors envisioned as replacements for the present operational sensors.

1. Current NOAA Series Spacecraft (NOAA E Through J)

The present NOAA-series polar-orbiting spacecraft (table XII-1) weighs more than 1,000 kg and carries an array of about eight sensors and data-relay systems, of which the most important are an AVHRR and an ensemble of three instruments lumped together as the TOVS. (Details of the NOAA E through J imager and sounder instruments are given in table XII-2.) These instruments (the HIRS, the SSU, and the MSU) provide sounding data, that is, values of emitted infrared and microwave brightness from the Earth's surface and atmosphere, from which profiles of the atmospheric temperature and moisture content aloft may be calculated. While the calculation of soundings formerly required a major meteorological processing center, this can now be carried out by a tabletop computer. Soundings form the major satellite input to worldwide numerical weather prediction, and are supplemented in prediction models by surface temperature values derived from AVHRR brightness values. (Winds calculated from apparent cloud motion as seen in sequential geostationary satellite images are also of great value.)

Three of the four instruments providing imagery and soundings from the NOAA-series platform (AVHRR, HIRS, and SSU) operate in the IR portion of the spectrum. (MSU is a four-channel microwave sounder unit.) Since clouds are opaque to the passage of infrared energy, neither surface temperatures nor soundings are possible through cloud cover using infrared instruments. In winter, when much of the continental United States is cloud decked, this causes a serious data loss. While coarse soundings can be calculated from MSU data, the MSU's four channels (between 50 and 57 GHz) do not describe a detailed profile of temperature or moisture versus height.

2. NOAA K, L, M

The major change planned for NOAA K and subsequent satellites is the installation of an AMSU (table XII-3), a 20-channel sounder operating in frequencies between 23 and 183 GHz, including the 50 GHz channels used in the MSU. HIRS is retained, while MSU and SSU are dropped. The resulting increase in sounding data is expected to reduce the error in soundings calculated from satellite data by about one-half. Other products to be calculated from AMSU microwave data include water vapor profiles, precipitation, and global sea ice coverage. Table XII-3 lists the channel characteristics for the AMSU, and figure XII-1 provides a chart showing the weighting functions for the AMSU-A.

Several of the AVHRR channels will be changed (table XII-3). Channels 1 and 2 will be modified to make the visible and near-IR data more useful for the calculation of a Vegetation

Table XII-1
Advanced TIROS-N (NOAA E Through J) Summary Sheet

Spacecraft	Total weight - 1,030 kg (2,270 lb) (excludes expendables)
Payload	Weight, including tape recorders 386 kg (850 lb)
Instrument Complement	Advanced Very High Resolution Radiometer (AVHRR/2) High-Resolution Infrared Radiation Sounder (HIRS/2) Stratospheric Sounder Unit (SSU) Microwave Sounder Unit (MSU) Argos Data Collection System (DCS) Space Environment Monitor (SEM) Search and Rescue (SAR) Satellite-Aided Tracking (SARSAT) Solar Backscatter Ultraviolet radiometer (SBUV/2) -NOAA F and on p.m. satellites only Earth Radiation Budget Experiment (ERBE) - NOAA F and G only
Spacecraft Size	3.71 m in length (165 in), 1.88 m in diameter (74 in)
Solar Array	2.37 m x 4.91 m: 11.6 m^2 (7.8 ft x 16.1 ft: 125 ft^2), 515 W, end of life at worst solar angle (high-efficiency solar cells)
Power Requirement	Full operation - 475 W Reserved - 40 W
Attitude Control System	0.2° all axes 0.14° determination
Communications	Command link - 148.56 MHz Beacon - 136.77; 137.77 MHz S-band - 1698; 1702.5; 1707 MHz APT - 137.50; 137.62 MHz DCS (uplink) - 401.65 MHz SAR - 1544.5 MHz SAR (uplink) - 121.5; 243.0; 406.0 MHz
Data Processing	All digital (APT translated to analog)
Orbit	833; 870 km nominal, sun-synchronous 0730 and 1330 local crossing times

Table XII-2
Polar Imagers and Sounders (NOAA E Through J)

Sensors and Functions

Advanced Very High Resolution Radiometer (AVHRR/2)
1.1 km resolution; <2,900 km swath width

Channels	Wavelengths (μm)	Primary Uses
1	0.58 - 0.68	Daytime cloud/surface mapping
2	0.725 - 1.10	Surface water delineation, ice and snow melt
3	3.55 - 3.93	Sea surface temperature, nighttime cloud mapping
4	10.30 - 11.30	Sea surface temperature, day and night cloud mapping
5	11.50 - 12.50	Sea surface temperature, day and night cloud mapping

TIROS Operational Vertical Sounder (TOVS)
(HIRS, MSU, and SSU make up TOVS)

1. High-Resolution Infrared Radiation Sounder (HIRS/2)
Nadir resolution 17.4 km

1-5	14.95 - 13.97	Temperature profiles, clouds
6-7	13.64 - 13.35	Carbon dioxide and water vapor bands
8	11.11	Surface temperature, clouds
9	9.71	Total ozone concentration
10-12	8.16 - 6.72	Humidity profiles, detection of thin cirrus clouds
13-17	4.57 - 4.24	Temperature profiles
18-20	4.00 - 0.69	Clouds, surface temperatures under partly cloudy skies

2. Stratospheric Sounding Unit (SSU)
Nadir resolution 147.3 km

1-3	14.97	Temperature profiles

3. Microwave Sounding Unit (MSU)
Nadir resolution 105 km

1	50.31 GHz	
2	53.73 GHz	Temperature soundings through clouds
3	54.96 GHz	
4	57.95 GHz	

Table XII-3
Polar Imagers and Sounders (NOAA K, L, M)

Sensors and Functions

1. Advanced Very High Resolution Radiometer (AVHRR/3)
   1.1 km resolution; <2,900 km swath width

Channels	Wavelengths (μm)	Primary Uses
1	0.58 - 0.68	Daytime cloud/surface mapping
2	0.84 - 0.87	Surface water delineation, ice and snow melt
3A	1.58 - 1.64	Daytime cloud/snow delineation, sea surface temperature
3B	3.55 - 3.93	Nighttime sea surface temperature and cloud mapping
4	10.30 - 11.30	Sea surface temperature, day and night cloud mapping
5	11.50 - 12.50	Sea surface temperature, day and night cloud mapping

2. High-Resolution Infrared Radiation Sounder (HIRS/3)
   Nadir resolution 17.4 km

1-5	14.95 - 13.971	Temperature profiles, clouds
6-7	13.64 - 13.35	Carbon dioxide and water vapor bands
8	11.11	Surface temperature, clouds
9	9.71	Total ozone concentration
10-12	8.16 - 6.72	Humidity profiles, detection of thin cirrus clouds
13-17	4.57 - 4.24	Temperature profiles
18-19	4.00 - 3.76	Clouds, surface temperature
20	1.90 - 0.04	Radiation budget, clouds

Table XII-3 (concluded)
Polar Imagers and Sounders (NOAA K L, M)

3. Advanced Microwave Sounder Unit (AMSU-A)
Nadir resolution 47 km

Channel	Center Frequency (GHz)	Bandwidth (MHz)	Use
1	23.900	270	Window
2	31.400	180	Window
3	50.300	200	Window
4	52.800	400	Temperature sounding
5	53.596	170	Temperature sounding
6	54.400	400	Temperature sounding
7	54.940	400	Temperature sounding
8	55.500	330	Temperature sounding
9	57.290344=f(10)	330	Temperature sounding
10	f(10)±217 MHz	78	Temperature sounding
11	f(10)±322.2 MHz±48 MHz	36	Temperature sounding
12	f(10)±322.2 MHz±22 MHz	16	Temperature sounding
13	f(10)±322.2 MHz±10 MHz	8	Temperature sounding
14	f(10)±322.2 MHz±4.5 MHz	3	Temperature sounding
15	89.0	6000	Precipitation, window

4. Advanced Microwave Sounder Unit (AMSU-B)
Nadir resolution 15 km

Channel	Center Frequency (GHz)	Bandwidth (MHz)	Use
16	89.0	6000	Precipitation, ice, window
17	166.0	4000	Window
18	183.0 ± 1.0	1000	Water vapor profiling
19	183.0 ± 3.0	2000	Water vapor profiling
20	183.0 ± 7.0	4000	Water vapor profiling

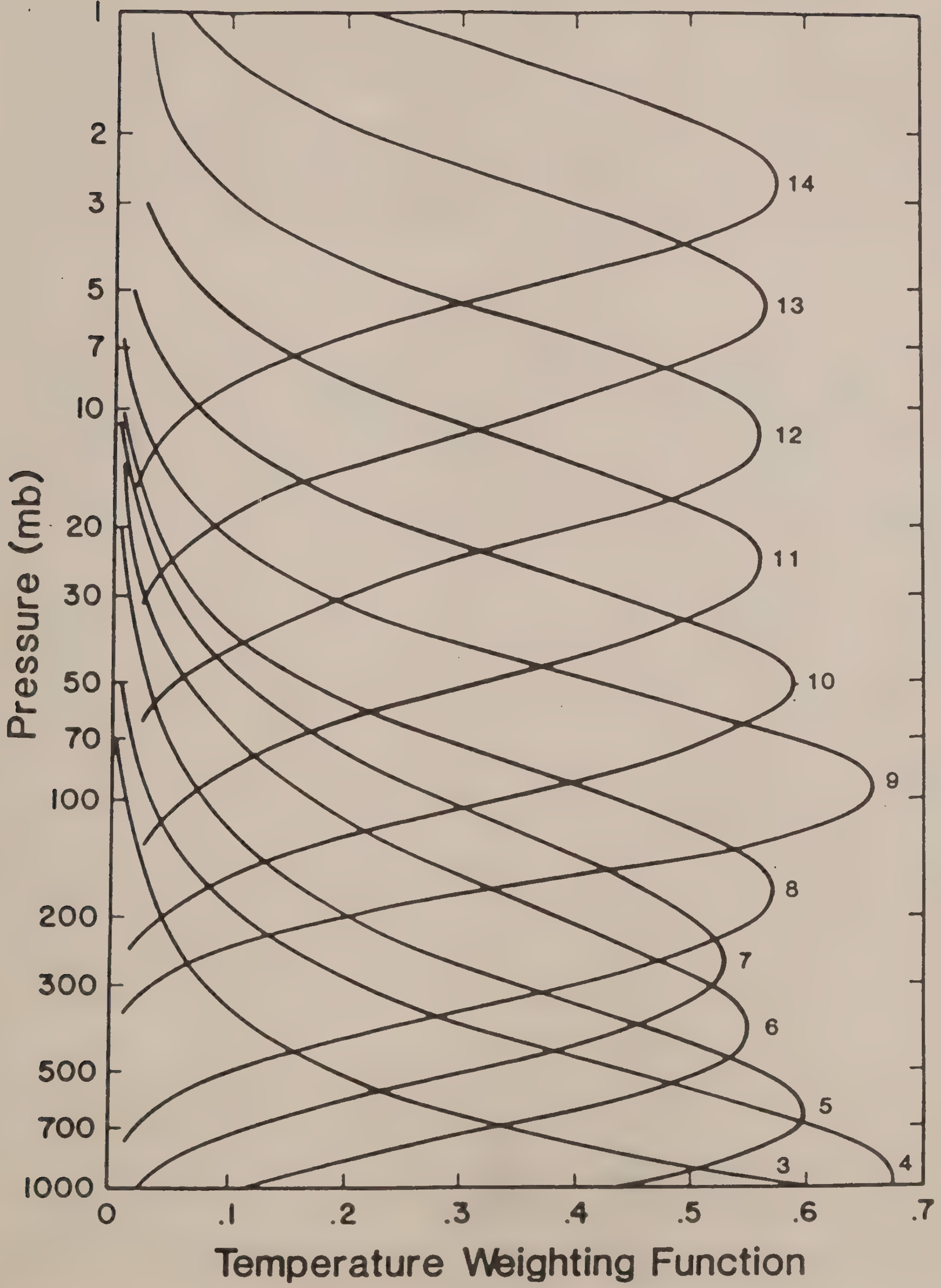


Figure XII-1
Weighting Function, AMSU-A, NOAA K, L, M

Index, a data product indicating the "greenness" of the region imaged (chapter XI). Channel 3 will be time-shared with a near-IR channel; the present channel 3 will be on during the night portion of the orbit, and the new channel will be on during the day portion of the orbit. The present channel 3 becomes channel 3B and remains unchanged in spectral content. Channel 3A, the new channel, will enhance determination of cloud cover versus surface snow and ice cover. For channels 1, 2, and 3A, outputs will be changed from the present linear output to a nonlinear output that will enhance the low-energy portion of the data (table XII-3).

The HIRS channel 20 is to be broadened to enhance its value as a data source for the Earth radiation budget. The change seeks to incorporate the Earth radiation budget data requirements into the HIRS, whereas in the present instruments these data are produced by the AVHRR. At present, the HIRS channel 20 covers only 0.6 to 0.7 micrometers. Replacement of a visible radiation (silicon) detector by a thermal radiation (germanium) detector in the channel will widen the spectral response from 0.2 to approximately 2 micrometers, without the necessity of an optical system redesign.

An orbital change is scheduled for NOAA H and subsequent spacecraft. The time for equatorial crossings is to be advanced from 1430 to 1330 local time. A sun-synchronous orbit is retained. The planned change required a thorough redesign of the spacecraft's thermal controls and instrument shades, since the spacecraft will observe the sun constantly at higher viewing angles during all sunlit flight times. The change is planned to coordinate eastern Pacific data collection with a change scheduled by the NWS, to move forward the startup time of its numerical prediction runs.

Installation of an ocean color instrument (OCI), similar to the earlier Coastal Zone Color Scanner (CZCS), is also under consideration for the NOAA K, L, M purchase. Flight of the OCI would increase data collection in support of near-shore marine interests, including fisheries and environmental monitoring of rivers, estuaries, and continental-shelf oceans.

Whether or not an ocean color instrument is added to NOAA K, L, and M, the addition of the AMSU will force a change in the telemetry bands used by the spacecraft for direct-to-user broadcasts. One of the beacon frequencies now used (136.77 MHz) falls into a band slated to be reallocated to use by commercial aviation, beginning in 1990. Various scenarios are now under consideration in an effort to achieve sufficient data flows with a minimum impact on spacecraft and ground station telemetry hardware, and also to minimize the cost impact on direct broadcast data users worldwide.

Tables XII-4 and XII-5 show payloads carried on NOAA D through M, and details of NOAA K, L, M changes.

3. Future DMSP and POES Microwave Sounder Complementarity

Microwave instruments will be flown on both DMSP and POES near-future spacecraft. These instruments will offer sounding and water-state observation advantages that have been discussed earlier in this document. Table XII-6 offers a summary comparison of the planned microwave sounders of the two programs.

4. Future NOAA Series Satellite Systems

With NOAA K, L, and M close to determined, extensive satellite improvements now are possible only aboard spacecraft to be purchased for launch in the decades of the 1990's and beyond. Proposals are under consideration within NOAA for a "block change," that is, for development of a new satellite bus to replace the existing spacecraft, in the early 1990's. NOAA's present planning for this block change is directed toward transferring the sensor and service complements of the POES mission to the polar-orbiting platforms of the U.S. Space Station program. This appears to be a logical use of the polar platform resource and it may also provide some budget advantages. Technical and funding reviews of this concept are under way between NASA and NOAA to quantify the conditions of NOAA's use of polar platforms as Earth remote-sensing observatories.

A companion volume in this ENVIROSAT-2000 Report series is Plan for Space Station Polar-Orbiting Platform, June 1985. The details of the possible utilization of the polar platform for the NOAA POES mission of the 1990's and beyond--sensors, systems, services, data handling, communications, management, and the like--are reported in that document.

Table XII-4
Projected Payload Complement for NOAA D Through M Satellites

Spacecraft	D	8	9	G	H	I	J	K	L	M
a.m./p.m.	a.m.	(a.m.)	p.m.	a.m.	p.m.	p.m.	a.m.	p.m.	a.m.	p.m.
Sched. Launch	11/88	(3/83)	(12/84)	10/86	10/87	1/89	11/89	1/91	11/91	1/93
Failed date		7/84								
Revived		6/85								
Instrument										
AVHRR	Yes	Yes	Yes	Yes/1	Yes	Yes	Yes	Yes/2	Yes/2	Yes/2
HIRS/2	Yes	Yes	Yes	Yes	Yes/1	Yes/1	Yes/1	Yes/2	Yes/2	Yes/2
AMSU	No	No	No	No	No	No	No	Yes	Yes	Yes
SSU	Dummy	Yes	Yes	Dummy	Yes	Yes	Dummy	No	No	No
MSU	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
DCS (Argos)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes/1	Yes/1	Yes/1
SAR	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SBUV/2	No	Ballast	Yes	No	Yes	Yes	No	Yes	No	Yes
ERBE Scanner	No	Ballast	Yes	Yes	Dummy	Dummy	Dummy	No	No	No
ERBE Non-Scanner	No	Ballast	Yes	Yes	Dummy	Dummy	Dummy	No	No	No
SEM, TED	Dummy	Yes	Dummy	Yes	Dummy	Yes	Dummy	Yes	Yes	Yes
MEPED	Dummy	Yes	Dummy	Yes	Dummy	Yes	Dummy	Yes	Yes	Yes
HEPAD	Dummy	No	No	No	No	No	No	No	No	No

NOTE: Ballast denotes addition to balance spacecraft center of gravity. Dummy denotes a physical simulation model with proper weight, thermal characteristics, and appropriate electrial terminations.

AVHRR - /1 denotes 4-channel instrument; /2 denotes 5.5-channel (one switched channel) instrument, with changed channel gains.

HIRS/2 - indicates instrument HIRS/2I, /2 shows HIRS/2II. (See text.)

DCS - /1 indicates a doubling of system capacity.

SBUV/2 - SBUV instrument is carried only on p.m. flights.

HEPAD has been shifted to the GOES spacecraft.

Table XII-5
NOAA K, L, M Changes

Communications

APT - 137.50; 137.62 MHz
S-band - 1698.0; 1702.5; 1707.0 MHz
DCS (uplink) - 401.65 MHz
SAR - 1544.5 MHz
SAR (uplink) - 121.5; 243.0; 406.0 MHz
Command link - S-band. Exact frequency not available.

Space Environment Monitor

No change from present system.

Ozone Monitor

Solar Backscatter Ultraviolet (SBUV) instrument. No change from present instrument. SBUV is carried only on the p.m. satellite.

Data Collection System

Upgraded capacity with memory and greater sensitivity in the receivers.

Search and Rescue

Upgraded sensitivity and capacity.

Table XII-6

Future Microwave Sounder Technical Comparison

Characteristic	SSM/T Atmospheric	SSM/T-2 Water Vapor	AMSU-A Atmospheric	AMSU-B Water Vapor
Spectral Channels	7 channels 50 GHz region	5 channels 91-183 GHz region	15 channels 23-90 GHz region	5 channels 90-183 GHz region
Data Distribution	Surface - 10 mb (30 km)	Surface - 500 mb	Surface - 1 mb (47 km)	Surface - 500 mb
Field of View	186 km at nadir 12° IFOV	46.5 km at nadir 3° IFOV (at 183 GHz)	47 km at nadir 3° IFOV	15 km at nadir 1° IFOV
Signal to Noise (NEΛT)	0.4 - 0.7 K	0.6 - 0.8 K	0.2 - 0.9 K	0.8 K
Dynamic Range	4 - 330 K	4 - 330 K	4 - 330 K	4 - 330 K
Digitization	12 bit	12 bit	14 bit	14 bit
Calibration	Space/internal blackbody	Space/internal blackbody	Space/internal blackbody	Space/internal blackbody
Line Rate	32 s/line	7.6 s/line	8 s/line	2.6 s/line
Scan Field of View	±36° from nadir 7 steps	±40.5 from nadir 28 steps	±49.5° from nadir 30 steps	±49.5° from nadir 90 steps
Weight	25 lb	30 lb	125 lb	70 lb
Power	14 W	30 W	115 W	70 W
Design Life	3 yr (4 yr goal)	3 yr (4 yr goal)	3 yr	3 yr
Cost	$2.5 M	$6.5 M	Being negotiated	Furnished by U.K.

XIII. NOAA ARCHIVING AND RETROSPECTIVE USERS

This section will discuss archiving by NOAA of POES and DMSP data and products, beginning with an overview of the primary NOAA satellite archive center, and followed by separate discussions of the NOAA POES archive data base and its users, and the NOAA DMSP archive data base and its users. In each case, the present and planned activities will be presented. The section will conclude with a discussion of NOAA's POES and DMSP satellite data archiving activities.

A. OVERVIEW OF THE NOAA SATELLITE ARCHIVE CENTER

The primary NOAA satellite archive center is the Satellite Data Services Division (SDSD) of the NESDIS National Climatic Data Center. SDSD is located in Suitland, Maryland, sharing facilities with the NESDIS Office of Satellite Data Processing and Distribution, which is the source of the NOAA POES data archived by SDSD.

As the primary NOAA satellite archive center, SDSD performs data management and user service functions. SDSD receives a steady stream of data and products, which are cataloged and added to the archive data base. The archive media for digital data is at present either TBM (Ampex Terrabit Memory) system tapes (2 in wide, high-density data tapes) or 1,600 bpi or 6,250 bpi CCTs (computer-compatible tapes). In the near future, the TBM system will be replaced by a combination of 6,250 bpi CCT and IBM 3480 cassette. In the longer term, conversion to an optical archive system is envisioned.

Catalogs of data and products resident on the archive data base exist in both hard copy and automated form, with gradual conversion to a fully automated catalog system in progress.

User services provided by SDSD include providing users with access to archive data base catalog information from which the user requests products, and then producing the requested products. Catalog information is available to users in hard copy form but, starting in 1985, users will also gradually be given access via terminal to catalog data bases (and the capability to place orders via terminal).

The products available to users from SDSD include reproductions of data and products (e.g., photographic reproduction of archive film or copies of archive tapes), but users most often request selective extracts based upon latitude-longitude, time or time period, or other data-related criteria. Products are provided by conventional mail or delivery service, and SDSD plans to experiment with limited delivery of digital products via telecommunications in the next year or so.

SDSD also maintains information concerning instrument calibration, satellite ephemeris, and the like, and publishes a set of users' guides that include descriptions of the satellites, instruments, data formats, data availability in general, and ordering procedures.

B. NOAA POES DATA--NOAA ARCHIVE DATA BASE AND USERS

1. Contents of the POES Archive Data Base

SDSD manages a comprehensive data base of POES data and products, ranging from the early TIROS series of polar orbiters through the current NOAA series. Table XIII-1 is a summary listing of the POES data included in the archive data base. Two primary classes of instruments have flown aboard POES satellites. In the first class are the imaging instruments, scanning radiometers (and their predecessors, vidicon cameras) used initially to generate visible and IR imagery and subsequently to produce quantitative products such as sea surface temperature analyses. The second class are the multichannel radiometers used to produce atmospheric sounding products. Scanning radiometer data have been archived in image form since the 1960's, both as individual scenes and as global polar stereographic and Mercator mosaics. The mosaics have also been archived in digital form since 1966.

In 1985, the archiving of imagery in the form of film negatives is being phased out as the operational system converts to the use of UNIFAX paper products (as opposed to photographic prints; the archive negatives were a by-product of the operational process). This will be replaced by a file of UNIFAX prints that can be reproduced photographically, supplemented by the capability to produce image products from digital data.

Beginning with TIROS-N in 1979, the archive data base includes global "level 1b" digital data from the imaging instrument (the AVHRR) and the sounding instruments (the HIRS, MSU, and SSU instruments). Level 1b data are raw data with calibration and Earth location information appended. The global AVHRR data are the 4 km-resolution GAC data. In addition, a sampling of 1 km AVHRR level 1b data is also archived.

In addition to the level 1b data, various products produced operationally are archived. These are listed in table XIII-2.

2. Near-Real-Time and Retrospective Users

NOAA POES level 1b AVHRR data are by far the most widely used digital data available from SDSD. For example, in FY84, $351,000 worth of POES level 1b AVHRR data sets (actually selective extracts from archive data sets) were provided by

Table XIII-1
Summary Listing of POES Satellite Data Archived by SDSD

Satellite	Launch Date	Dates of Data Archived	Form	Instruments
TIROS-1	4/ 1/60	4/ 1/60 - 6/14/60	I	Vidicon
TIROS-2	11/23/60	11/23/60 - 9/27/61	I	Vidicon, IR radiom.
TIROS-3	7/12/61	7/12/61 - 1/23/62	I	Vidicon
TIROS-4	2/ 8/62	2/ 8/62 - 6/18/62	I	Vidicon, IR radiom.
TIROS-5	6/19/62	6/19/62 - 5/14/63	I	Vidicon
TIROS-6	9/18/62	9/18/62 - 10/21/63	I	Vidicon
TIROS-7	6/19/63	6/19/63 - 2/26/66	I	Vidicon, IR radiom.
TIROS-8	12/21/63	12/21/63 - 2/12/66	I	Vidicon
TIROS-9	1/22/65	1/23/65 - 9/ 9/66	I	Vidicon
TIROS-10	7/ 2/65	7/ 2/65 - 4/ 2/66	I	Vidicon
ESSA-1	2/ 3/66	2/ 4/66 - 10/ 6/66	I	Advanced vidicon camera system (AVCS)
ESSA-3	10/ 2/66	10/ 4/66 - 6/ 1/67	I/D	AVCS and low-resolution IR radiometer (LRIR)
ESSA-5	4/20/67	6/ 1/67 - 12/ 3/68	I/D	AVCS, LRIR
ESSA-7	4/16/68	4/16/68 - 3/31/69	I/D	AVCS, LRIR
ESSA-9	2/26/69	4/ 1/69 - 11/15/72	I/D	AVCS, LRIR
ITOS-1	1/23/70	4/28/70 - 6/17/71	I/D	Scanning radiometer (SR)
NOAA-1	12/11/70	4/26/71 - 6/20/71	I/D	SR
NOAA-2	10/15/72	11/16/72 - 3/19/74	I/D	SR, VHRR, VTPR
NOAA-3	11/ 6/73	3/26/74 - 12/17/74	I/D	SR, VHRR, VTPR
NOAA-4	11/15/74	12/17/74 - 9/15/76	I/D	SR, VHRR, VTPR
NOAA-5	7/29/76	9/15/76 - 3/16/78	I/D	SR, VHRR, VTPR
TIROS-N	10/13/78	10/30/78 - 11/ 1/80	I/D	AVHRR, TOVS
NOAA-6	6/27/79	6/27/79 - 6/20/83 6/21/84 - Present	I/D	AVHRR, TOVS
NOAA-7	6/23/81	6/23/81 - 2/18/85	I/D	AVHRR, TOVS
NOAA-8	3/28/83	6/20/83 - 6/12/84	I/D	AVHRR, TOVS
NOAA-9	12/12/84	12/28/84 - Present	I/D	AVHRR, TOVS, SBUV, ERBE

Form: I - Image, D - Digital

Table XIII-2
Operational POES Products Archived by SDSD

1. Operational TOVS Sounding Product (Digital)

   Layer mean temperatures for 15 layers, precipitable water for three layers, tropopause and total ozone information, equivalent blackbody temperatures for HIRS, MSU, and SSU channels. Spatial resolution nominally 250 km.

2. Digital Sea Surface Temperature (SST) Product Set

   a. SST observations (temperature retrievals, 50 km nominal spacing)
   b. SST regional analysis (three regions, each of 10,000 grid points on 1/2° lat/long mesh)
   c. SST global scale analysis (1° or 100 km lat/long grid)
   d. SST climatic scale analysis (5° or 500 km lat/long grid)
   e. SST monthly means (2 1/2° or 250 km lat/long grid)

3. Analog Sea Surface Temperature Product Set

   a. GOSSTCOMP charts - weekly Mercator contour charts, each a 50° by 50° lat/long segment, 1 °C contour interval
   b. Regional charts - set of three charts covering the U.S. 200-mile conservation and management zone
   c. Great Lakes and Gulf Stream charts

4. Heat Budget Product (Digital)

   Daytime longwave flux, nighttime longwave flux, available solar flux, reflected solar flux, 2 1/2° lat/long Mercator grid supplemented by polar chips.

5. AVHRR GAC Mapped Mosaics (Digital and Image)

   Polar stereographic (1,024 by 1,024 hemispheric arrays - 15 to 30 km resolution) and Mercator arrays, daytime visible, daytime and nighttime IR.

6. Pass by Pass Gridded Imagery

   AVHRR GAC imagery, global coverage, 8 km resolution. By September 1985, 4 km resolution GAC imagery produced from digital data will be available by user request (specifying channels, enhancement, coverage).

7. High-Resolution Imagery

   AVHRR HRPT/LAC 1 km resolution imagery, visible and IR data. By September 1985, 1 km resolution HRPT/LAC imagery produced from digital data will be available by user request specifying channels, enhancement, coverage).

SDSD, accounting for 37 percent of all of SDSD's FY84 sales of data and products. SDSD offers near-real-time service, in which data sets or extracts are provided to users within 24 to 48 hours of their acquisition. This service has been especially popular for users of high-resolution (HRPT/LAC) AVHRR level 1b data sets; of the 2,209 such data sets provided by SDSD in FY84, 1,452 data sets, or 66 percent, were provided on a near-real-time basis. Table XIII-3 summarizes the POES services performed by SDSD during FY84.

Table XIII-3
POES Data and Products Provided by SDSD in FY84

AVHRR Level 1b GAC Data Sets	3,426
AVHRR Level 1b HRPT/LAC Data Sets	2,209
TOVS Level 1b Data Sets	2,883
AVHRR HRPT/LAC Hard Copy Image Products	3,963
Sea Surface Temperature Digital Product Tapes	159
Sea Surface Temperature Charts	12,479
TOVS Atmospheric Sounding Product Tapes	216
Other POES Digital Products, Tapes	199
Other POES Hard Copy Products	4,135
Other POES Hard Copy Charts	22,069

SDSD provided POES products to a wide variety of users in FY84. Table XIII-4 is a breakdown by user class of the dollar value of the services provided.

As Table XIII-4 illustrates, the heaviest use of POES data is by NOAA and other Federal agencies for a wide range of applications, including agricultural monitoring and oceanographic applications, as well as meteorological and climatological applications. In fact, by application the POES users break down roughly into 40 percent oceanographic, 40 percent meteorological, and 20 percent other (primarily agricultural).

SDSD is currently involved with two special efforts involving POES data. The first of these is production of a weekly composite global Vegetation Index product under Agricultural and

Table XIII-4
POES Data Users by User Class, FY84

User Class	Digital Orders	Hard Copy Orders	Dollar Value
Other NOAA Agencies	280	186	128,200
Other Federal Govt.	458	82	344,800
State and Local Govt.	0	1	12
Private Industry	135	143	53,551
University Researchers	80	154	29,847
Private Individuals	0	85	1,631
Foreign Govt.	18	17	13,167
Other Foreign	145	206	63,257

Resources Inventory Surveys through AgRISTARS sponsorship (chapter XI). The Vegetation Index is produced from AVHRR visible data. The second is the production of a global sampled (24 km resolution) AVHRR data set for the International Satellite Cloud Climatology Project (ISCCP).

3. Planned Changes in NOAA's POES Archive Data Base and User Services

The POES data base will include data and products from several new instruments as these become operational. The first of these is the SBUV; another is the AMSU, successor to the current MSU instrument. The NOAA K, L, M series will also include an improved version of the AVHRR. Basically, however, the content of the POES data base will be relatively stable prior to implementation of the polar platform; no radically new instruments or changes in resolution, data rates, etc., are planned.

The major change in user services planned by SDSD for the remainder of the 1980's is the gradual evolution of an on-line user services capability. The first steps in this direction, planned for 1985-86, will be to offer users access to an interactive catalog and order-taking system that will include as its first module a catalog of POES AVHRR HRPT/LAC and GAC data sets. Limited tests of electronic transmission of selected AVHRR data sets to a small number of test users are also planned. Eventually that catalog will include all POES data and products (and GOES and other data included in the SDSD data base as well) and, as justified by the results of initial tests, an expanded electronic data transmission capability. The catalog system will be accessible via inexpensive "dumb" terminals, and will also support access by personal computer (PC)-based terminals. PC-based terminals will be able to display coverage of data sets graphically (i.e., a box showing the area covered by a data set overlaid on a base map) or to receive a portion of the catalog data base for off-line browsing by the user.

Other changes in POES services planned include implementation during 1985 of the capability to make hard copy image products from digital data, and the prototype of an electronic videodisk-based, PC-controlled imagery browse file system, which will also operate as a "smart" terminal of the interactive catalog system.

C. DMSP DATA--NOAA ARCHIVE DATA BASE AND USERS

1. Contents of the DMSP Archive Data Base

NOAA presently archives a variety of DMSP data and products, and will greatly expand its DMSP data base after the implementation of shared processing (see chapter X). SDSD maintains an archive of DMSP digital data in Suitland and an archive of DMSP film imagery in Boulder, Colorado, through a contract with the National Snow and Ice Data Center (NSIDC), which is affiliated with the University of Colorado.

The present DMSP digital data base maintained by SDSD includes only raw data (with Earth location appended) from the SSH and SSM/T instruments (which are similar, respectively, to the POES HIRS-2 and MSU instruments).

The DMSP imagery collection held at NSIDC includes three different products provided as positive transparencies by the AFGWC. The products are produced from high resolution (fine) and lower resolution (smooth) data obtained from the DMSP OLS instrument, which is comparable in some respects to the POES AVHRR. The three products are:

- Sporadic coverage at 0.6 km resolution visible and IR imagery obtained from DOD direct readout sites located at various places about the world, with most coverage of the western United States, Europe, and Southeast Asia. These images are comparable to POES HRPT images, and indeed some DOD tactical stations can receive POES HRPT data. Some of the imagery in the collection are HRPT images. Imagery in the collection dates back to 1973.

- Global coverage of 2.7 km resolution visible and IR data as single orbit strips (i.e., comparable to POES pass-by-pass products). Imagery in the collection dates back to 1973.

- Polar stereographic mosaics compiled from a sequence of orbits mapped at 5.4 km resolution. Mosaics are available from December 1975 through the present.

2. Retrospective Users

There have been only three or four users ever to request any of the digital SSH or SSM/T raw data from SDSD. A variety of users access the imagery collection resident at NSIDC, although the volume is very much less than the use of POES image products. NSIDC averages 90 data requests per year, in response to which 900 products are photographically reproduced for users; 2,200 products from the collection are loaned to users.

3. Planned Changes in NOAA's DMSP Archive Data Base and User Services

Major changes and expansion of the archiving by SDSD of DMSP digital data are planned over the period from 1985 through the early 1990's. These changes will be associated with the implementation of shared processing. DMSP data (originating from AFGWC) and products (originating from AFGWC and FNOC) received by NOAA via the shared processing communications system will be added to the SDSD archive data base. These will include:

- SSM/I (microwave imager) raw data (with Earth location)
- SSM/I antenna temperatures
- SSM/I brightness temperatures
- SSM/I environmental data records

The SSM/I products will be produced by FNOC starting shortly after the launch of Satellite S-10, the first DMSP satellite with an SSM/I. This will occur on a launch-on-demand basis not earlier than the second quarter of FY86. These products will be provided to SDSD on magnetic tape until the shared processing communications system becomes operational in late 1986.

The satellite global data base is a higher resolution visible and IR polar stereographic mapped array (4,096 by 4,096) comparable to the mosaics produced currently from POES (on 1,024 by 1,024 arrays). In addition, SDSD will archive the atmospheric sounding products to be produced by NOAA from SSM/I and SSM/T data.

It is expected that there will be a great deal of user interest in the SSM/I products, especially the brightness temperatures and the environmental data records. As soon as possible, SDSD is planning to include information about these products in the interactive catalog system described earlier.

XIV. CONCLUSIONS

A. OVERVIEW

The civil weather satellite program, operated by NOAA, and the defense program, operated by the U.S. Air Force, have worked closely together, with ever-increasing commonality, since the declassification of the DMSP system in the mid-1970's. Because the basic missions are different, amalgamation of the two programs has twice (in 1974 and 1979) been rejected as a matter of Federal policy. Nevertheless, the technical similarities have made possible many cost-saving measures. Most notable among the steps that have been implemented are the use of common spacecraft buses and the sharing of processing workloads. These areas of commonality are described in this report. In addition, data from both programs have been shared to supplement both missions and to back up deficiencies when they occurred.

The mission objectives of the two systems are different, however, and demand a number of divergent ways of providing operational services. The orbital requirements of the NOAA system are designed to support the global and regional forecasting requirements of the National Weather Service. (See the ENVIROSAT-2000 Report, NOAA Satellite Requirements Forecast, May 1985.) Those of the DMSP are designed to support the needs of this Nation's defense requirements and, in particular, the necessary flexibility to meet possible threats. [See the ENVIROSAT-2000 Report, Federal Agency Satellite Requirements, July 1985; and the Defense Meteorological Satellite System (DMSS) System Requirements Document (DMSS-100), Dec. 14, 1983.] The system continuity requirements (criteria for relaunch of failed spacecraft) differ because the primary mission of POES is to produce quantitative global inputs to numerical forecasts, while the primary mission of DMSP is to produce global high-resolution imagery.

In general, the clientele are different, with the DOD system serving a relatively narrow defense community, while POES serves the global community of civil users with virtually no distinction between "allies" and "nonallies." As a direct result, the POES spacecraft have many features that would be difficult to implement for DMSP (e.g., provision of the U.S. SARSAT service; direct broadcast of all data "in the clear;" public dissemination of schedules and status of spacecraft), while some DMSP requirements would be difficult and needlessly expensive for NOAA (e.g., protection of downlink data, hardening). The DOD must retain full operational control of the DMSP system at all times, while NOAA can accept some requests from outside agencies or governments for special services. This has led to the ability to carry foreign subsystems on POES, such as the SSU from the United Kingdom, the Argos data collection system and SARSAT 406 MHz subsystem from France, as well as other parts of the SARSAT system from Canada.

The purpose of this document, as stated in chapter I, is to establish a technical baseline (phase A) from which can be mounted the next step in the evolution of the process--investigation of possibilities for future cooperation and cost savings. This next step (phase B) will be undertaken during FY86 and FY87 as approved funded studies, and will be performed by contractors to be selected. In this way, the 1986-87 studies will be as nonparochial as possible, and should not require extensive interaction with government personnel who must operate the system while the next phase is going on. Because the detailed knowledge about the current system is mainly in the minds of government personnel, it was necessary that this first step be undertaken by those persons most closely associated with the system. With the current study in hand, it will be possible to provide the selected contractors with a comprehensive, unclassified, up-to-date description of the purposes, capabilities, applications, and methods of operation of these two systems.

B. OUTLOOK

It is not the intention of this report to prejudge the outcome of phase B. "Outlook" here is intended to be a broad, professional estimate rather than a forecast.

Cooperation will continue and intensify in those areas where technical similarities exist. This will be complicated to some extent by NOAA's possible transition, in the mid-1990's, to the U.S. Space Station polar platform for its POES requirements. (See the ENVIROSAT-2000 Report, Plan for Space Station Polar-Orbiting Platform, June 1985.) The reason for this consideration is that the polar platform offers improvements in observational capability and reliability, while offering potential cost savings by joining with other missions such as the NASA Earth Observation System (EOS) program. In that same timeframe, the DOD forsees a system that is more secure, autonomous, survivable, and responsive to DOD operational requirements in times of international tension or conflict.

Nevertheless, there are areas where increased joint efforts can be logically predicted. The DOD and NOAA have already identified mutual interests in instrument developments, including the following:

- Microwave imaging devices
- Microwave temperature and water vapor sounders
- Space environment monitors

Both agencies are already implementing the centers of expertise philosophy for ground data processing (see chapter X), and this is likely to continue with the development of new products not currently in the inventory. This effort will probably lead to the sharing of findings with regard to generic factors affecting satellite data processing. The sharing of data processing techniques could expand from ground-based technology to the space portion of the systems as the increasing complexity of space-derived data leads to the necessity for preprocessing in orbit.

APPENDIX A
GLOSSARY OF ACRONYMS

AAC - Alaskan Air Command
A/D - Analog to Digital
ADACS - Attitude Determination and Control Subsystem
ADE - Array Drive Electronics
AET - Aerospace Engineering Technician
AFGWC - Air Force Global Weather Central
AFSCF - Air Force Satellite Control Facility
AFSCN - Standardized Air Force Satellite Control Network
AFTAC - Air Force Technical Applications Center
AFU - Alaskan Forecast Unit
AGE - Aerospace Ground Equipment
AgRISTARS - Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing
AGROMET - Agricultural Meteorology Program
AGS - Ascent Guidance Software
AKM - Apogee Kick Motor
ALC - Automatic Level Control
ALP - Ascent Load Package
ALU - Arithmetic and Logic Unit
AMSU - Advanced Microwave Sounding Unit
AOS - Acquisition of Signal/Acquisition of Satellite
APE - Ascent Phase Equipment
APL - Applied Physics Laboratory
APT - Automatic Picture Transmission
ASAT - Anti-Satellite System
ASW - Anti-Submarine Warfare
ATNAGE - Advanced TIROS-N Aerospace Ground Equipment
AVCS - Advanced Vidicon Camera System
AVHRR - Advanced Very High Resolution Radiometer
AWS - Automatic Weather Stations/Air Weather Service (USAF)

B - Battery
BCX - Battery Charger Assembly
BECO - Booster Engine Cut-off
BES - Budget Estimate Submission
BLM - Bureau of Land Management

C&CS - Command and Control Subsystem
CASID - Climate Air-Sea Interactive Drifter (Buoy)
CCC - Command Control Center
CCIR - Consultative Committee on International Radio
CCR - Cloud Cover Radiometer
CCS - Command and Control System
CCT - Computer-Compatible Tape
CDA - Command and Data Acquisition

CDDF - Central Data Distribution Facility
CIU - Controls Interface Unit
CMS - Control and Monitoring Subsystem
CNES - Centre Nationale d'Etudes Spatiales
CNO - Chief of Naval Operations
COE - Center of Expertise
COSPAS - Cosmicheskaya Sistyema Poiska Avariynich Sudov (U.S.S.R.)
CPC - Control Power Converter
CPU - Central Processing Unit
CRD - Command Receiver/Demodulator
CRS - Command Readout Station
CS - Communications Subsystem
CSA - Celestial Sensor Assembly
CSAF - Chief of Staff (USAF)
CV - Command Verification
CVSD - Continuously Variable Slope Detector
CZCS - Coastal Zone Color Scanner
C^2 - Command and Control
C^3 - Command, Control, and Communications
C^{3}S - Command, Control, and Communications Segments

D/A - Digital to Analog
DACS - Data Acquisition and Control Subsystem
DCPL - Data Collection and Platform Location
DCS - Data Collection System
DESS - Defense Environmental Satellite System
DET - Direct Energy Transfer
DG - Data General/Defense Guidance
DHS - Data Handling Subsystem
DMSP - Defense Meteorological Satellite Program
DMSS - Defense Meteorological Satellite System
DOC - Department of Communications (Canada)
DPSS - Data Processing and Services Subsystem
DPU - Data Processing Unit
DRB - Defense Resources Board
DRS - Data Reconstruction System/Direct Readout Site
DRU - Data Recovery Unit
DSB - Direct Sounder Broadcast
DSIS - Defense Satellite Information System
DTR - Digital Tape Recorder

ECMWF - European Centre for Medium-Range Weather Forecasts
EDR - Environmental Data Records
ELT - Emergency Locator Transmitter
ELV - Expendable Launch Vehicle
EMA - Electrodynamics of the Middle Atmosphere
E/O - Electro-optical
EPIRB - Emergency Position-Indicating Radio Beacon

EPOCS - Equatorial Pacific Ocean Climate Study
ERBE - Earth Radiation Budget Experiment
EROS - Earth Resources Observation Systems
ESA - Earth Sensor Assembly
ESM - Equipment Support Module
EST - Equipment Status Telemetry

F - Fine
FAA - Federal Aviation Administration
FGGE - First Global Atmospheric Research Program (GARP) Global Experiment
FGMDSS - Future Global Maritime Distress and Safety System
FLP - Flight Load Package
FNOC - Fleet Numerical Oceanography Center
FOC - Final Operating Capability
FOV - Field of View
FYDP - Five-Year Defense Plan

GAC - Global Area Coverage
GAP - General Availability Program
GARP - Global Atmospheric Research Program
GATE - GARP Atlantic Tropical Experiment
GLOB - Glare Obstructor
G.m.t - Greenwich Mean Time
GPS - Global Positioning System
GTS - Ground Test Software/Global Telecommunication System

HA - Heatshield Assembly
HEPAD - High-Energy Proton and Alpha Detector
HILET - High Linear Energy Transfer
HIRAS - High-Resolution Analysis System
HIRS - High-Resolution Infrared Radiation Sounder
HRI - High-Rate Instrument
HRPT - High-Resolution Picture Transmission
HTS - Hawaii Tracking Station

ICAO - International Civil Aviation Organization
ICS - Integrated Commanding System
IF - Intermediate Frequency
IFC - In-flight Calibration
IFOV - Instantaneous Field of View
IG - Interdepartmental Group
IMO - International Maritime Organization
IMP - Instrument Mounting Platform
IMU - Inertial Measurement Unit
INMARSAT - International Maritime Satellite Organization

IOC - Initial Operating Capability
IONS - Ionospheric Sensing
IPAM - Improved Point Analysis Model
IPOMS - International Polar-Orbiting Meteorological Satellite
IR - Infrared
ISCCP - International Satellite Cloud Climatology Project
ISS - Integrated Spacecraft Segment
ITU - International Telecommunications Union

JCS - Joint Chiefs of Staff
JIC - Joint Ice Center

L - Light
LAC - Local Area Coverage
LACIE - Large-Area Crop Inventory Experiment
LBH - Lyman Birge-Hopfield
LF - Light Fine
LFM - Limited-area Fine Mesh
Lidar - Light Detection and Ranging
LF/TS - Visual Fine/Thermal Smooth
LOLET - Low Linear Energy Transfer
LOS - Loss of Signal
LRI - Low-Rate Instrument
LRIR - Low-Resolution IR Radiometer
LRR - Long-Range Radar
LS - Light Smoothed
LS/TF - Visual Smooth/Thermal Fine
LUT - Local User Terminal

MAC - Military Air Command
MAG - Memory Address Generator
MAJCOM - Major Command
MCC - Mission Control Center
MEPED - Medium-Energy Proton and Electron Detector
MIRP - Manipulated Information Rate Processor
MMD - Mean Mission Duration
MOU - Memorandum of Understanding
MSC - Meteorological Satellite Coordinator
MSDF - Multiprocessor Software Development Facility
MSS - Multispectral Scanner
MSU - Microwave Sounding Unit
MVP - Mutual Visibility Period
MYP - Multiyear Procurement

NASA - National Aeronautics and Space Administration
N-ROSS - Navy Remote Ocean Sensing System

NCDC - National Climatic Data Center
NEARSS - Northeast Area Remote Sensing System
NEMS - Nimbus-E Microwave Spectrometer
NERSAC - Naval Environmental Remote Sensing Coordinating and Advisory Committee
NESDIS - National Environmental Satellite, Data, and Information Service
NETD - Noise Equivalent Temperature Difference
NG - Nested Grid
NMC - National Meteorological Center
NMFS - National Marine Fisheries Service
NOAA - National Oceanic and Atmospheric Administration
NOC - Naval Oceanography Command
NOS - National Ocean Service
NSC - National Security Council
NSDD - National Security Decision Directives
NSIDC - National Snow and Ice Data Center
NVI - Normalized Vegetation Index
NWS - National Weather Service

OAR - Office of Oceanic and Atmospheric Research
OCI - Ocean Color Instrument
OLS - Operational Linescan System
OMB - Office of Management and Budget
OPC - Ocean Product Center
OR - Operational Requirements
ORSTOM - Office de la Recherche Scientifique et Technique Outre Mar
OSC - Ocean Service Center
OSD - Office of the Secretary of Defense
OSU - Oregon State University
OTSR - Optimum Track Ship Routing

PACS - Precision Antenna Calibration Source
PBD - Program Budget Decision
PC - Power Converter/Personal Computer
PDM - Program Decision Memorandum
PE - Program Element
PEM - Program Element Monitor
PIP - Programmable Information Processor
PMC - Pressure Modulated Cell
PMP - Precision Mounting Platform
PMS - Power Management Software
PMT - Photo Multiplier Tube
POES - Polar-orbiting Operational Environmental Satellite
POM - Program Objective Memorandum
PPBS - Planning, Programming, Budgeting System
PREMAP - Precipitation and Soil Moisture Mapping
PRESSURS - Prestrike Surveillance/Reconnaissance System

PRL - Polar Research Laboratories
PRT - Platinum Resistance Thermistors
PSE - Power Supply Electronics
PSE/BCA - Power Supply Electronics/Battery Charge Assembly
PTF - Payload Test Facility
PTT - Platform Transmitter Terminal

RCC - Rescue Coordination Center
RCE - Reaction Control Equipment
RDU - Receiver Demodulator Unit
REAMOS - Remote Atmospheric Soundings
RF - Radio Frequency
RFI - Radio Frequency Interference
ROM - Read Only Memory
RSS - Reaction Control Subsystem Support Structure
RTD - Real-Time Data
RTNEPH - Real-Time Nephanalysis
RTS - Remote Tracking Station
RWA - Reaction Wheel Assembly
RXO - Redundant Crystal Oscillator
RYC - Roll/Yaw Coils

S - Smoothed
SA - Solar Array
SAD - Solar Array Drive
SAD/ADE - Solar Array Drive/Array Drive Electronics
SAR - Search and Rescue/Synthetic Aperture Radar
SARP - Search and Rescue Processor
SARR - Search and Rescue Repeater
SARSAT - Search and Rescue Satellite-Aided Tracking
SATCU - Solar Array Telemetry Commutating Unit
SBUV - Solar Backscatter Ultraviolet Instrument
SCAMS - Scanning Microwave Spectrometer
SCF - Satellite Control Facility
SCU - Signal Conditioning Unit
SDF - Stored Data Fine
SDHS - Satellite Data Handling System
SDR - Sensor Data Records
SDS - Stored Data Smoothed
SDSD - Satellite Data Services Division
SECDEF - Secretary of Defense
SEL - Space Environment Laboratory
SEM - Space Environment Monitor
SEQUAL - Seasonal Equatorial Atlantic Study
SESC - Space Environment Services Center (NOAA)
SFSS - Satellite Field Services Station
SGDB - Satellite Global Data Base
SIDS - Satellite Imagery Dissemination System
SIG - Senior Interdepartmental Group

SIO - Scripps Institute of Oceanography
SMOP - Satellite Measurement of Oceanographic Parameters
SNR - Signal to Noise Ratio
SOC - Satellite Operations Center
SOCC - Satellite Operations Control Center
SOG - Satellite Operations Group
SON - Statement of Operational Need
SOP - Standard Operational Procedure
SPC - Satellite Processing Center
SPO - System Program Office
SPU - Sensor Processing Unit
SR - Scanning Radiometer
SS - Space Segment
SSB/A - X-Ray Spectrometer (DMSP Sensor System)
SSD - Sun Sensor Detector
SSI/E - Topside Ionospheric Plasma Monitor (DMSP Sensor System)
SSI/ES - Ionospheric Plasma Drift/Scintillation Monitor (DMSP Sensor System)
SSH - Infrared Temperature Sounder (DMSP Sensor System)
SSJ - Space Radiation Dosimeter (DMSP Sensor System)
SSM/I - Sensor System Microwave/Imager (DMSP Sensor System)
SSM/T - Sensor System Microwave/Temperature Sounder (DMSP Sensor System)
SSM/T-2 - Sensor System Microwave Water Vapor Sounder (DMSP Sensor System)
SST - Sea Surface Temperature
SSU - Stratospheric Sounding Unit/Sun Sensor Unit
SSUV - Vacuum Ultraviolet Spectrometer (DMSP Sensor System)
STIP - Stored Low-Rate Data
STS - Space Transportation System
STX - S-Band Transmitter

T - Thermal
TAXI - Total Auroral X-Ray Index
TBM - Terrabit Memory
TCE - Thermal Control Electronics
TCLBS - Tropical Constant Level Balloon System
TCS - Thermal Control Subsystem
TDR - Temperature Data Records
TED - Total Energy Detector
TF - Thermal Fine
TGS - Triglycine Sulphate
TIDS - Tactical Imagery Dissemination System
TIP - TIROS Information Processor
TIROS - Television and Infrared Operational Satellite
TOGA - Tropical Ocean Global Atmosphere Program

TOVS - TIROS Operational Vertical Sounder
TS - Thermal Smoothed
TU - Transport Unit

UADB - Upper Air Data Base
US - User Segment
USAF - U.S. Air Force
USDA - U.S. Department of Agriculture

VHF - Very High Frequency
VHLET - Very High Linear Energy Transfer
VI - Vegetation Index
VSWR - Voltage Standing Wave Ratio
VTPR - Vertical Temperature Profile Radiometer
VUV - Vacuum Ultraviolet

XBT - Expendable Bathythermograph
XSU - Cross-Strap Unit

WEFAX - Weather Facsimile
WES - Western European System (Station)
WMO - World Meteorological Organization
WOCE - World Ocean Climate Experiment